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The History of Engineering

A Course of Lectures

to

The Senior Engineering Students

of the

Iowa State College, Ames, Iowa.

By

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PREFACE.

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Six years ago it became the duty of the Dean of Engineering to give a course of instruction in the History of Engineering to the Senior Engineering students of Iowa State College. As no text book exists on this subject, it was necessary to employ the lecture method, and the same plan was followed one year later.

As was expected, only a limited portion of the great field of Engineering History could be touched upon by this method during the time allotted to the lectures, and the lecture notes made by the students themselves were not, in general, of a very satisfactory nature. The labor of accumulating and studying the great mass of data bearing on the subject progressed so far by 1908, that it seemed best to present their main features in the form of mimeograph notes, as far as time permitted. About ninety pages of such notes were prepared at that time, and used for the classes of 1908 and 1909. This was increased to over 200 pages in 1910. It is now proposed to thoroughly revise and greatly extend these notes on the History of Engineering, and to have them printed instead of mimeographed. It is hoped that in this way a considerably greater amount of ground can be covered, and that the most important features of the lectures can thus be presented in better form for preservation. However, the notes will be supplemented by lectures each week, during which there will be shown a large number of illustrative lantern slide views. Undoubtedly much of the work of the present semester will be presented entirely by lectures, as it will be impossible to complete the printed notes on the entire subject for some time to come. Hence each student will be expected to supplement these notes to the fullest possible extent by his own notes, taken during the lectures. The examinations will not be restricted to the printed notes, but will cover the entire subject matter of the lectures.

The writer hopes to be able to continue his study of the History of Engineering for many years to come, and that he may thereby be able to continue extending and revising these notes until they reach a fairly complete and permanent form, amounting eventually to a manuscript text book on the subject.

PART I.

PRELIMINARY DISCUSSIONS AND DEFINITIONS.

CHAPTER I. INTRODUCTION.

1. **The History of Engineering.** No history of engineering has yet been written. It is a subject lying outside of the province of the ordinary historian, who is wholly unequipped with the technical knowledge required for its study and elucidation. The subject is also outside the ordinary province of the engineer, for, when written properly, the History of Engineering will be found to consist of much more than a mere chronicle and description of engineering achievements, and to have had a most profound influence upon the history of mankind. The proper writing of the history of our profession will require the searching out of its world-wide relations. It will call for a broad general training, added to the highest technical knowledge, and will demand both the ability and the time for many years of patient research into all branches of the development of civilization.

The world-wideness of the subject, its technical nature, the pressing character of an engineer's regular duties, and the short period of time which has elapsed since the recognition of engineering as a profession, fully account for the fact that as yet no attempt has been made to write the history of engineering.

2. **Engineering History and the Engineer.** Yet, when properly written, the study of engineering history will be most important to the engineer.

For one thing, no calling can be considered worthy to be ranked as a profession until it is imbued with such real professional spirit and enthusiasm as to know and to take pride in its ancestry.

Besides this, each engineer is rightful heir to the accumulated knowledge and skill of all the generations of his predecessors. He should be familiar with the history of their efforts and achievements, so as to begin his work at the point where they left off, and to be able, in his turn, to do something to increase the heritage of the profession. He should study, not only the details of present practice, but also the steps by which that practice has been developed. Thus in his own work he may be enabled to profit by the experience of his predecessors, and avoid the mistakes by which they learned. Engineering history should be able to tell him whether any new suggestion or invention has or has not already been tried and found wanting.

Furthermore a careful study of engineering in the past may frequently suggest new points of departure for new professional achievements.

Engineering history is also important to the engineer by broadening and enlarging his view of his profession. No person can achieve the greatest successes in engineering who is not a man of the broadest character, able to meet a myriad responsibilities of not strictly technical nature. The man who can plan and build a Panama Canal must have a wider knowledge of the world's commerce than any great merchant; he must have the address to convince an entire nation of the correctness of his ideas; he must have the business ability to carry out the enterprise against difficulties greater than those ever encountered by a business corporation. What better study could he take up than that of the history of the canals of the world, and their effect upon the development of commerce and civilization? So with other branches of engineering; their history is linked indissolubly with the history of mankind in general, in a myriad ways whose understanding would contribute invaluably to the proper training of the engineer.

3. **Engineering History and General History.** The great influence of engineering history upon general history is well illustrated by the fact that archaeology has classified the different conditions of human culture strictly in accordance with the state of development of engineering industry and invention. Thus we have the "stone age" (savagism), in which tools and weapons were made mainly of stone, and the "bronze age" (barbarism) and

the "iron age" (civilization), in which again the principal engineering material for tools and weapons gives its name to the culture period. Tools and other engineering devices are essential to any industrial development. An able writer* on "Mankind in Ancient Times" says "industry is the foundation and main force of savage culture," and that the invention of bronze tools "elevated mankind from savagism to barbarism." Archaeology, therefore, gives great prominence to ancient engineering in studying the development of culture and civilization.

Ordinary historians, however, have not, as it seems to the writer, given in their study sufficient attention to engineering inventions, processes, materials, and knowledge as most important factors in history. Thus one of the well known historians** of civilization in the Middle Ages devotes an entire chapter to a discussion of "What the Middle Ages Started With," in which he discusses at length literature, art, philosophy, science, law and government. He devotes only a part of the last page of the chapter, however, to the great subject of the industrial and mechanical side of civilization. His remarks will be quoted here verbatim, as illustrating both the very great importance of the subject, and the naive way in which a good historian can practically ignore some of the most important and fundamental factors affecting history, merely because some special technical knowledge is required for their adequate study and presentation.

"We must remember, however, in closing this chapter, that we have omitted, even from this general sketch, one large side of civilization, to which we can give no adequate treatment here or elsewhere. It is what may be called the economic and mechanical side. There passed over to the Middle Ages from the ancients large gains of this sort. Knowledge of the mechanical arts, acquired skill and inventions; methods of agriculture and navigation; organized trade and commerce, not all of which disappeared; accumulations of capital, cleared and improved land, houses, roads and briges, many of which continued in use across the whole of medieval times; administrative methods, both in general and local government; in a word, all sorts of practical knowledge and training, and many mechanical appliances. The economic influence of the Roman Empire affected in many ways indeed the larger movements of history. The comparative free trade which the empire established, the constitution of the Roman villa, or farm, the beginning of the process which transformed the slave into the serf, the forced dependence of the small landholder upon the large one, are important instances. These things constitute together, in some respects, the most primary and fundamental departments of civilization, and must not be forgotten, though, with the exception of a few instances which we shall notice, they demand, like the greater part of political history, special and specific treatment."

If history is to be more than a mere chronicle of events, and is to include as essentially a part of itself adequate discussions and explanations of its great underlying causes, then it would appear necessary that the history of engineering should be written, for the benefit not only of the engineer, but of mankind in general.

Taking, for example, the history of the marvelous development of our own country, it is granted by every one that it was made possible only by the steamship, the canal, the railroad, the modern bridge, and the telegraph. Without these means of transportation and communication, the vast interior of our continent would have required many centuries for its conquest. Yet in our histories we find but brief and most inadequate discussion of these great engineering achievements, each of which has been of far greater importance to the world than any war ever waged. A detailed history of the development of any one of these engineering achievements would show self sacrifice, devotion, energy, persistence, and courage even to death, on the part of many men. Its bare facts would read like the most imaginative romance. The men in the '60's and '70's who built our first transcontinental railways across the western plains in spite of deserts and savages, were in

*Hittell—Vol. I, p. 325, and Vol. II, p. 12.
**Civilization during the Middle Ages—G. B. Adams.

many cases the same who had fought to save the union in the Civil War just preceding, and were doing equally great service for their country. History should as fully remember the later service as the earlier.

The entire tremendous development of modern civilization which began with the great mechanical inventions of gun powder, the compass and the printing press, has been very largely due throughout to great mechanical inventions and engineering achievements.

Between 1750 and 1815, for example, the invention and development of the spinning jenny, the power loom, the use of coal in smelting iron, and the steam engine, gave England that world preeminence in industry and commerce which enabled her to conquer India, and to defeat Napoleon's attempt to subjugate Europe. History should adequately describe and discuss these underlying causes of such great events.

Again, in our own country, the invention of the cotton gin and of successful machinery for the manufacture of cotton fabrics, fastened slavery upon us at a time when it was in process of natural extinction, while it was the vast development of the mechanical industries of the northern states which enabled the Union to win in the great struggle for preservation of unity, thereby emancipating the slaves. We have many volumes of history devoted to the great struggle, yet none of them adequately discuss these powerful and foundamental factors.

And just as history seems largely to have overlooked the fact that engineering industrial development may be said to have freed millions of *black* slaves, so it gives little or no discussion of the sewing machine, the self binder, the telephone, and a myriad kindred engineering inventions and processes which have freed vastly many more millions of *white slaves*, on the farm and in the home, and which have fed and clothed the whole world.

We are now reading every day of the men who are risking and devoting their lives to assist in the conquest of the air. There can be no shadow of doubt that this new engineering achievement will continue, in the immediate future, the profound effect of engineering upon history.

4. **Antiquity of Engineering.** President Eliot, of Harvard, has stated in a public address that the profession of engineering is the oldest known to history. This is undoubtedly true when we take engineering in the broad sense in which it will be discussed throughout these lectures, and which is indicated by the great definition incorporated since its adoption in the charter of the British Institution of Civil Engineers; viz., "the art of directing the great sources of power in nature for the use and convenience of man." According to this generally accepted definition, engineering properly includes all utilization by mankind of the materials of construction, and of the mechanical forces and laws of nature.

The magnitude of each engineering achievement must be measured by its *relative* importance in the civilization of its own day.

Thus the invention of the first rude tools of stone was one of the greatest engineering achievements of mankind. The fact that man is the only tool inventing animal constitutes one of the principal differences between him and the brutes, and gave him the mastery of the world. The ever increasing utilization of physical forces and materials has been one of the most fundamental factors of the development of civilization.

Hence it may be said that engineering is far more ancient than history. At the earliest dawn of recorded history, we find in Ancient Egypt the record of so great an engineering achievement as the actual changing of the course of the river Nile,* an engineering feat so great that it would be difficult even to the engineers of today, and which presupposes thousands of years of previous development. Engineering not only antedates history, but, in fact, must be considered to be as old as mankind itself.

Yet while the great antiquity of engineering is not to be disputed, the recognition of the engineer as a member of a learned profession has been

*At Memphis, said by Herodotus to have been accomplished by Menes, a king of the 1st Dynasty, perhaps 5000 B. C.

very recent. Not until the first half of the 19th century did such recognition really begin, and not until the last half of that century did it really obtain. Prior to 1800 the engineer (except when devoting himself mainly to architecture) was usually regarded as a mere master workman, or mechanic. Law, medicine and theology were the only "learned professions." The engineer had no special schools, no technical societies, no code of ethics or professional organization, and was not held in high popular esteem.

In fact we have the apparent paradox that engineering is at once the youngest and the oldest of the learned professions.

There are a number of reasons why the progress of the recognition of engineering as a most honorable profession was so slow.

In the first place, the engineer, more than any other professional man, has to do in his daily work with absolute truth; with laws of the universe, which, while difficult to discover and understand, are absolutely rigid and unvarying in their operation. Thus he and his work must be absolutely true and unpretending, for chicane has never been of the least avail to deceive a physical law, nor has ignorance ever been accepted in excuse of its least infraction. On this account engineering has never been able to advance faster than man's real scientific knowledge of the universe would safely warrant. By no amount of hocus pocus is it ever possible for the engineering profession successfully to pretend to mysterious knowledge not really possessed; for a structure or machine not in accordance with true physical law will always fail, and thus expose the incompetency of its contriver.

To illustrate, the able theologians who propounded and defended the terrible doctrine of infant damnation, received high honor and respect from their own generation and church, upon which they succeeded in impressing that hideous mistake by their great ability in argument. Contrast this with the dreadful humiliation and reproach which have punished the able and honest engineers who designed the fallen Quebec bridge, for having stepped but one pace in advance of the known limits of established engineering knowledge. The comparison will help us to understand why engineering was never able to command equal rank with theology and medicine until the time of the recent wonderful advances in scientific knowledge.

Again, the lawyer found it possible in ancient times for governments to compel obedience to the most cruel and unjust laws by sheer despotic force, but the engineer has never had at his command any other means for compelling the adoption of his ideas than actual demonstration of their usefulness to mankind. Utility to humanity, the criterion by which all professions must be tested and finally ranked, has always been the immediate and rigid rule of judgment of engineering. In all ages the main applications of engineering knowledge and skill have been to meet the daily needs of the masses of mankind, rather than to aggrandize and glorify engineers. While, therefore, many a king or official has endeavored to claim for himself the credit of some great engineering achievement, the engineer must trace his ancestry among the little esteemed multitude of ancient artisans rather than among those limited classes which wrung power and fame from the sufferings of the multitude.

To the rigid engineering requirements of exact truth to physical law, and of actual demonstration of utility to humanity, and to the humble ancestry of the engineer, we must attribute the slow recognition of the profession of engineering, which is as old as the human race, and which in the pyramids of Egypt reared the greatest mass of masonry ever yet constructed, at a time when law was still largely the arbitrary enforcement of a Pharoah's whim, when medicine still struggled to propitiate imaginary demons by its incantations, and when priests still ruled nations by superstitious dogma for their own aggrandizement. It should be the pride of engineers that the recognition of our profession did not come until the enlightenment of the present day.

5. **An Outline Summary of Engineering History.** Engineering is so intimately related to the development of civilization that the most significant classification of engineering history will be in accordance with the culture periods of human development. This classification will, therefore, be adopted

in preference to a strictly chronological arrangement, though it may require the presentation of the pyramids of Mexico as really more ancient examples of engineering construction than those built at least 4,000 years earlier in Egypt. Following this plan, we shall have the following

CLASSIFICATION OF ENGINEERING HISTORY.

A. **Engineering in the Savage Culture Stage,** including prehistoric engineering and engineering among savages during the historic period. Mention will be made of the Pleistocene savages, whose tools and weapons have been found in central Europe in conjunction with geological evidence of extreme antiquity. Of later development in the savage culture state are the Swiss lake villages of Europe, and the mound and pueblo builders of North America. Among modern savages we may still find examples of most stages of development of savage culture.

B. **Engineering in the Culture Stage of Barbarism,** including engineering in Ancient Mexico, Peru, China, India, Egypt, Chaldaea and Assyria, Asia Minor and Persia.

Note.—Hittell also classifies the ancient Teutons and Celts and modern Mohammedans, as barbarians.

C. **Engineering in the Ancient Greek and Roman Civilizations,** including a period of about 1,000 years, from, say 600 B. C. to 400 A. D., and in area including all the regions extending from India to the British Islands, but especially the countries bordering on the Mediterranean Sea.

D. **Engineering in the Middle Ages.** This period also includes about 1,000 years, extending from, say 400 A. D. to 1400 A. D. The region is the same as for C above.

E. **Early Modern Engineering,** 1400-1750 A. D. The region of activity now widens to include practically the entire world.

F. **The Steam Age,** 1750-1850 A. D.

G. **Present Day Engineering,** 1850-Present Time. Present day engineering is so complex that in addition to a general survey of the subject it is necessary to make a detailed study of each of its important branches, such as:

1. Canal Engineering.
2. Road Engineering.
3. Steam Engineering.
4. Railway Engineering.
5. Marine Engineering.
6. Harbor Engineering.
7. Waterways Engineering.
8. Water Power Engineering.
9. Irrigation Engineering.
10. Drainage Engineering.
11. Sewerage Engineering.
12. Water Supply Engineering.
13. Tunnel Engineering.
14. Bridge Engineering.
15. City Engineering.
16. Street Railway Engineering.
17. Mining Engineering.
18. Ceramic Engineering.

Etc., etc.

19. Metallurgical Engineering.
20. Iron and Steel Engineering.
21. Gas Engineering.
22. Power Plant Engineering.
23. Factory Engineering.
24. Manufactures and Arts.
25. Chemical Engineering.
26. Agricultural Machinery.
27. Electricity.
28. Electric Power Engineering.
29. Electric Light Engineering.
30. Electric Railway Engineering.
31. Telegraph Engineering.
32. Telephone Engineering.
33. Military Engineering.
34. Architectural Engineering.
35. Engineering Societies.
36. Engineering Education.

We may briefly summarize the history of engineering during the above periods as follows:

6. A. **Outline of Engineering in the Savage Culture Stage.** The duration of the past life of mankind is still uncertain, but a number of good authorities have estimated it at about 200,000 years. The exact length of time is not very material to our discussion of engineering history. Assuming that the estimate of 200,000 years is approximately correct it may be said that much the greater part, or about 185,000 to 190,000 years, of the life of mankind have been passed in savagism. Only during the last 8,000 to 12,000 years has a small portion of the human race been in a higher state of culture, rising first from savagism to barbarism. Only 2,500 years ago a still smaller portion of mankind emerged from barbarism to early civilization. At the present time civilized man has conquered the world, and is rapidly spreading civilization over its entire surface, but the savages and barbarians still outnumber the civilized races. Hittell estimates that the present population of the globe includes about 250,000,000 of the black race, 600,000,000 of the yellow race and 550,000,000 whites. The blacks are nearly all in savagism. The yellow race are partly savage, but mostly in the barbaric stage; though the Japanese, the first of any yellow race, have just made good a claim to civilization. Not even all of the white race can be classed as civilized.

All but a small fraction, therefore, of the life of mankind has been passed in the savage culture stage. This immense period was one of imperceptibly slow progress in mechanical and other engineering lines, just as in all other culture. Each small advance came as the result of long and painful experience, by which the simplest and most elementary principles had to be learned over and over again, by generation after generation. However, such principles, when finally learned, became the permanent property of whole races, and so the foundations for mankind's later amazing advances were broadly and surely laid.

A careful enumeration of the achievements of savagism will show that they were many in number, and of the most fundamental importance to humanity. They include, in engineering lines: The discovery of the simple properties of many materials of construction, such as stone, wood and earth; some knowledge of minerals and metals as found in the natural state; the invention of many simple tools and processes; and the discovery of the operation of many elementary physical laws as encountered in every day life. The principles of the inclined plane, the wedge, the block and tackle, the beam and column are found in use in the savage tribes of the present day.

The arts of dressing leather, of spinning threads, of weaving baskets and cloth, and the manufacture of pottery are achievements of savagism.

Savage races developed land transportation by human labor, and water transportation by canoes and boats, propelled by paddles, oars and finally by sails.

They also invented and developed many ingenious implements and weapons, including the bow and arrow, and the sling. The prevailing material for implements and weapons was stone.

The oldest stone tools and weapons found are so rude in nature that the very fact of their really being the product of human intelligence was long disputed. On the other hand, the corresponding polished stone implements of the highest savage culture show, probably, the highest possible development of that material.

In the latest period of the stone age, many savage races have come to fashion part of their ornaments and implements out of native copper, which is found in many lands, but its softness made the metal inferior to stone for cutting tools. Independently, as their knowledge of how to make very hot fires improved, many races have eventually made the discovery that copper could be hardened by the admixture of a comparatively small percentage of tin. This invention of bronze gave a material very much superior to stone for the manufacture of cutting tools, and lifted men from savagism to barbarism.

7. B. **Outline of Engineering in the Barbaric Culture Stage.** During the barbaric culture stage, progress in culture became very much more rapid.

The various arts and handicrafts became the special occupations of organized crafts, by whose agency the knowledge acquired by experience was handed down and improved upon from generation to generation.

The small individual tribes of savagism became welded into great nations, whose organized energies, wielded by despotic governments, could be directed to the accomplishments of great enterprises. To this period of engineering belong those immense pyramids, reared of earth in Mexico, and in Egypt of solid masonry, to be the enduring monuments of religion and ambition. To barbarian nations must also be credited the stupendous irrigation canals of Chaldaea, the Great Wall and the Grand Canal of China, and the two thousand mile roads of Peru, construction demanded by the necessities of subsistence, defense and commerce.

Thus to the barbaric culture stage belong some of the greatest constructive achievements of engineering, accomplished not by the aid of mysterious mechanical appliances, as sometimes conjectured, but by the concentrated efforts of tens of thousands of men, compelled to their tasks by the whips of despotic authority.

In barbaric nations, the instinctive appreciation of art, which crude attempts at its expression show to exist universally, even among the rudest savages, became highly developed, and, when expressed through constructive engineering, gave rise to great architectural monuments, which are still the wonder and the admiration of the world.

Mining engineering developed to the point of operating regular mines for gold, silver, tin, copper, and perhaps certain other minerals, including finally iron.

Marine engineering developed from a very early date. The construction of ships, propelled by both oars and sails, and large enough for ocean service, was undertaken and accomplished. Extensive military and merchant navies were developed by many barbaric nations.

Though the rate of progress in culture in the barbaric stage was still almost imperceptibly slow, as compared with the present, yet it was very rapid as compared with the savage stage, and in a relatively few thousands of years, artisans learned to make fires in their furnaces hot enough to smelt iron. Soon the mastery of this material was attained to such an extent that it supplanted bronze, which is vastly inferior in utility. The abundant introduction of iron marked the beginning of the civilized culture stage.

8. C. **Outline of Engineering in the Ancient Greek and Roman Civilization, 600 B. C.-400 A. D.** About 2,500 years ago the first civilization was developed, by the ancient Greeks and Romans. The empiric scientific data accumulated during ages of savagism and barbarism, and handed down by the daily practice of thousands of generations, or preserved in royal and priestly libraries, were now collected and discussed by men of genius, whose names are still household words in science.

With the beginning of real science, engineering, under the name of architecture, and allied to art, received its first recognition as a profession. There is still extant one of the old Roman books on architecture, in which the union of engineering and architecture in one profession is attested by its chapters on water supply and machinery.

Among the ancient Greeks, art received perhaps the highest development ever yet known and hence their greatest constructive achievements were not utilitarian structures, but those wonderful temples, which purely as expressions of art, have never since been equalled in architecture. Along with the names of her great men in literature, painting and sculpture, Greece was justly proud to preserve in history that of the architect of the Parthenon.

The Romans, who finally obtained the mastery of practically the entire ancient civilized world, were greatly inferior to the Greeks as artists, but greatly superior as engineers. Grecian architecture, however beautiful, was not well suited to the utilitarian needs of a great empire with its many different races and climates. Even the Grecian temples, though wonderful expressions of art, were not well suited to be the places of worship of a deeply religious people, nor at all adapted to rigorous climates. Roman

architecture, therefore, achieved its triumphs in a great variety of structures devised to meet public needs, rather than in high artistic excellence. It boasts of the basilica, the public baths, the Circus Maximus, the Colosseum and the triumphal arch, rather than of its temples. It was in the new invention of these structures, in their vast size, in the magnificence of their materials and ornamentations, and in their ingenious engineering details of construction, that Roman architects surpassed the Greek.

To the Roman engineer-architect must be given the credit of adopting and developing the semicircular arch, which has been independently devised by many barbaric nations, but which was never before extensively put to actual use. One cause of the artistic inferiority of Roman architecture was that the use of the arch required a long period of development before entirely suitable systems of ornamentation could be devised.

When we consider the more purely engineering work of the Romans, our admiration requires no qualification. Their mastery of the principle of the arch enabled them to build monumental bridges which endure to the present day. Yet these bridges did not surpass, as purely engineering structures, Caesar's pile bridge, so rapidly thrown across the Rhine, nor Trajan's great wooden arches across the Danube.

Mastery of the arch principle also led to the construction of the many great masonry aqueducts, built for the public water supply systems, not only of Rome, but of practically all cities of importance throughout the entire empire; those aqueducts which have never since been equalled for magnitude of elevated masonry water channels, and whose remains are still the admiration of the most highly skilled modern engineer. Great tunnels were also numbered among the common feats of the Roman water supply engineer, while in the cities he laid tons upon tons of lead distribution pipes to conduct the water from the public reservoirs to the public baths, and to the residences of the wealthy. A photograph of a collection of ancient plumbing fixtures reminds one most decidely of the show window of a modern establishment in the same handicraft.

Sewers are everywhere the necessary accompaniment of water supply systems, and hence received proper attention from the Romans. The Cloaca Maxima, or great sewer, of Rome, is still partly in use, though dating from the early history of the city, and has been indispensable to the very existence and preservation of the imperial city.

The Romans were also skilled in the drainage of agricultural lands, and had an excellent system of public land surveys.

Roman engineers were great road builders, and the network of massive and enduring highways with which they covered their entire empire must be reckoned among its most important achievements.

Ancient shipping, which we find frequently pictured on the monuments of Egypt, received very extensive development among the Phoenicians, and later among the Greeks, and was of the utmost importance to the Romans. They built extensive docks and artificial harbors. Their galleys were unsurpassed for speed until the modern age of steam, and some of the ancient Mediterranean grain ships almost equalled in size a modern ocean steamer.

In mechanical appliances, a considerable beginning was made at development. They had pile drivers and derricks to use for construction purposes. Water wheels and pumps were in actual use. The water clock was one of a number of ingenious mechanical contrivances, rather scientific curiosities than machines, among which was embodied the idea of the steam engine, though not in a working form.

The military engines of the Greeks and Romans were very powerful and effective, and were unsurpassed until some time after the invention of gun powder. Military engineering, in general, as regards both the attack and defense of cities, was highly developed, and some of the ancient walls and moats and siege constructions were of very great magnitude.

We should not omit, in an outline of engineering among the Romans, to make mention of their mining operations. By slave labor, organized on a large scale, they conducted extensive mining and smelting operations for iron,

copper, tin, gold and silver. In Spain, for example, the mines for copper and iron were on an especially large scale. The tin mines of Cornwall, England are another example of famous ancient mines.

9. D. **Outline of Engineering in the Middle Ages, 400 A. D.-1400 A. D.** At a time when it was greatly weakened by internal corruptions and dissensions, for which, had not outside forces intervened, a remedy from within would doubtless have been found in time, the Roman Empire was assailed on all sides by sturdy, uncontaminated barbarian peoples, and, after repeated assaults, was almost entirely conquered and overrun. Now was illustrated the fact that mere actual knowledge by a few individuals of mechanical contrivances and principles is not sufficient to make them available for the use of the whole race, for, though her mechanical knowledge was free to her invaders, it required a thousand years for the barbarian conquerors of Rome fully to acquire her ancient civilization.

During this period of the dark ages, engineering, like other phases of culture, seemed to have retrograded. The magnificient Roman water supply and sewerage systems fell into decay and misuse, while pestilence after pestilence almost depopulated the unsanitary mediaeval cities. The network of Roman roads was no longer kept up so that even adjoining communities lived in ignorance of each other, unable longer freely to communicate and trade. The ancient masterpieces of architecture were often used as quarries for material to build the strongholds of robber nobles.

The retrogression was, however, more apparent than real. Knowledge of the ancient handicrafts, and of engineering and architectural principles, was never entirely lost. More and more they became the property of the entire European people, until the Renaissance ended the Dark Ages by a period of enthusiastic study of the ancient civilization which finally made it entirely the possession of Europe.

Moreover, the virile Teutonic conquerors of Rome introduced new elements of progress and strength, and, free from the ancient taint, stood equipped, at the beginning of modern times, for the greatest epoch yet witnessed in the world's history.

The necessities of ocean commerce and intercourse between nations in the Middle Ages maintained in use modified ancient ships, or galleys, propelled by oars and sails.

Much of the energy of the Middle Ages was directed along military lines, and they witnessed the development of steel armor, and of the fendal castle. The military engines, however, were inferior to those of the Romans.

The development of industry brought about the organization of powerful guilds. The masonic fraternity had to do with actual masonry construction. There were even "brotherhoods of the bridge," devoted to bridge construction.

It was in religious architecture, however, that the Middle Ages made their greatest constructive achievements. The Roman basilica developed into the early Christian church, and expanded use of the semi-circular Roman arch gave the Romanesque style of architecture. In the eastern, or Grecian empire, which alone of the Roman dominions had escaped conquest by barbarians, Byzantine architecture grew out of the Roman, while the Mohammedan invaders of the south and east, along with a brilliant literature and science, developed the Arabian or Saracenic architectural style. The extreme religious devotion typical of the Middle Ages called for more adequate architectural expression than was afforded by the Romanesque, with its monotonously rounded semi-circular arches. Hence in France and other portions of Europe, there was developed, at about 1000 to 1200 A. D., the Gothic style, with its pointed arches and slender spires aspiring heavenward. For hundreds of years a large part of the energy of an extensive community would be directed to the erection of one of the great Gothic cathedrals, dominating the entire city, and sculptured from top to bottom with religious representations, a veritable "prayer in stone." However towards the close of the Middle Ages, there came with the Renaissance a revival of the classic architectural styles of ancient Greece and Rome.

10. **Modern Engineering.** Since 1400 A. D., the development of engineering has been so extensive that when the history of engineering really comes to be written all preceding that date will constitute but a few introductory chapters to a bulky volume. It has been stated truly that if the engineering work constructed in the last 100 years alone were to be abandoned for 2000 years like those of the ancients, they would then by far exceed all that mankind had accomplished permanently to mark the face of the earth prior to the last 100 years.

11. E. **Early Modern Engineering. 1400 A. D. to 1750 A. D.** The beginning of the period was signalized by the adoption by Europe of the great inventions of gunpowder the printing press, the compass, and the canal lock. The earliest manufacture of cast iron rather than wrought iron, as the first product of iron ore, also dates in the 14th or 15th century.

The introduction of the use of gunpowder exalted the artisan and democracy in general, while destroying feudalism. It entirely changed the art of fortification and attack, and called for new manufactures of armament and ammunition, and new methods of transportation. The developments along these lines are still going on most vigorously. Thus gunpowder revolutionized military engineering, and we may add that thereby a great stimulus has been given to many branches of civil engineering as well.

The printing press greatly stimulated intellectual activity, and thereby especially aided the advancement of scientific knowledge, which is the foundation of engineering. The printing press also facilitated that rapid cooperative development of any new invention, and its mastery by a large number of people, which seem essential to its permanent success.

The compass revolutionized the art of navigation, and therefore also revolutionized shipping and marine engineering in general. It thus enabled the sway of civilization to be extended to America, and indeed to the entire world.

The invention of the canal lock is supposed to have occurred about 1439, and it eventually revolutionized internal transportation and profoundly affected commerce. The Canal of Briare, in France, completed in 1642, was the first summit level canal. The great Languedoc Canal in southern France, connecting the Atlantic Ocean with the Mediterranean sea, was completed in 1681, and for 140 years was the greatest artificial waterway of western civilization.

Ever since 1400 the work of the great scientists and mathematicians has been placing engineering upon an ever more extensive and solid foundation of scientific knowledge. Galileo and Newton were but two of the many of the many great physical scientists of the early modern epoch, whose discoveries have been the real cause which has made engineering a profession.

About the beginning of the 17th century an organization of a corps of royal engineers was effected in France by Sully, the comrade and minister of Henry IV. Indeed, Guizot states that "Sully covered the country with roads, bridges, canals, buildings and other works of public utility," a statement doubtless somewhat exaggerated.

In 1664 the French Academy of Science was established by Colbert, the great minister of Louis XIV. Colbert also improved the roads, introduced new and encouraged old manufactures, and did much to promote commerce and shipping. It is stated that the first school of science was established in France in 1748.

At about this same period, Vauban and Cochorn revolutionized military engineering, and by their great achievements in fortifications and sieges did much to give fame to the calling of the engineer. Vauban was made a marshal of France in recognition of his ability as a great military engineer.

Small arms and artillery had now become highly efficient, and great engineering problems of transportation had to be solved to make feasible the operations of the great armies of Turenne and Marlborough.

Marine engineering had also by this time become greatly developed, both for war and commerce, in so far as concerned the construction and navigation of sailing vessels, and the oceans were now easily traversed by the navies of the world.

In 1660 the Greenland dock was built at London, remaining the only one in that port until the 19th century. The first dock at Liverpool was begun in 1709. Other European harbors received similar engineering improvements.

11. F. **Outline of history of modern engineering in the steam age. 1750 to 1850 A. D.** This period of 100 years has for its preeminent engineering achievement the development of the steam engine. Little had been accomplished with this agency prior to 1750, while by 1850 it had been developed to very high efficiency, had been applied to all its greatest uses, and stood preeminent, with hardly a rival. Since 1850, electricity and the gas engine have become great rivals and associates of steam.

Although general progress in scientific knowledge and in the development of mechanical industries and engineering in general was very rapid from 1400 A. D. to 1750 A. D., as compared with the thousand preceding years, yet the great industrial revolution was reserved for the last half of the 18th century. Indeed a well known historian* has made the sweeping statement that "At the middle of the 18th century all the industrial arts were being carried on in practically the same way that they were followed six or seven thousand years before in ancient Egypt and Babylonia." Doubtless this statement is greatly exaggerated, but in the manufacture of cloth, for example, each thread was still being done seperately by hand in 1750, and the weaving was still being done on hand looms. Iron was still smelted by charcoal fires, and was consequently scarce and costly. For power, men had supplemented human strength, to any considerable extent, only by animals, wind mills and rude water wheels.

Suddenly all this was changed by a series of great inventions. Hargreaves devised the spinning jenny about 1767, and Arkwright perfected the invention. Cartwright added the power loom in 1785, and now one person could accomplish the work of hundreds in the manufacture of cloth. Soon after, the invention of the cotton gin in America, by Eli Whitney, gave all the raw material needed.

During these same years Watt perfected the steam engine, and the great English coal deposits came to be utilized, in the form of coke, for smelting as well as for fuel. Thus iron and power could now be had for manufacturing at a low cost, and to any desired amount.

It has very justly been pointed out that it was the manufacturing and commercial supremacy secured to England by these great industrial improvements which enabled her to win in the great Napoleonic wars which followed.

Cheap transportation, especially for interior regions, was still lacking after the great inventions enumerated above, but now Brindley and his compeers in England, and the French engineers covered those two countries with great networks of canals. To supplement the cheap water carriage of the canals, Great Britian built networks of fine stone roads, and in France the military highways of Napoleon, like himself, scaled the Alps. The names of the British engineers Macadam and Telford are still used to characterize the two principal methods of building stone highways.

Highways and canals enormously stimulated the development of manufacturing and commerce, and soon their needs required other and still more efficient modes of transportation. In 1807, Fulton, in America, made the first really successful application of steam to navigation. Soon the steamboat was common on inland and coast wise waters, and in 1838 the Great Western, designed by Brunel, demonstrated the practicability of steam trans-Atlantic navigation.

Meantime, George Stephenson, in 1829, had, on the Liverpool and Manchester Railroad, finally demonstrated the success of the steam railway. Europe and America were soon provided with great railway systems.

The construction and operation of railways greatly stimulated both mechanical and civil engineering, which were as yet one profession. Not only constantly improved locomotives, and great shops, were called for, but also improved railroad track, great cuts, bridges, embankments, tunnels, and the highest degree of engineering skill in the economic location of railway lines, and in overcoming difficulties in construction and operation.

*Myers

Nor should we forget the work of the mining engineers. Without their work in developing the economical mining of coal and iron, and the metallurgical processes of manufacturing iron, none of the other engineering work could have been done. Indeed, it was mining engineers who first made successful use of the steam engine itself. Mining engineering was of great importance in the history of the modern world in another way. The search for precious metals, perhaps more than any other one thing, was the motive which led on to the discovery and civilization of the unexplored portions of the earth's surface

To meet the engineering demands of the epoch extending through the last half of the 18th and the first half of the 19th century, a group of great British engineers was developed, some of whose names have been immortalized by Smiles in his "Lives of the Engineers." Mention may be made of John Smeaton, James Watt, Mathew Boulton, James Brindley, George and Robert Stephenson, Thomas Telford, John Rennie and I. K. Brunel. These were self taught men of genius who learned their calling in the hard and expensive, but thorough, school of experience, for there were no technical institutions of learning in their time. Perhaps the great success of these men delayed the foundation of engineering schools in England, for there grew up a system of apprenticeship in that country whereby young engineers secured their training by serving as apprentices in the office of established engineers, paying liberally for the privilege. In 1818 the British Institution of Civil Engineers was founded.

In America there were practically no real engineers until well into the 19th century, though Washington was but one of many early American surveyors. A French engineer, L'Enfant, was employed to lay out the plan of Washington, the capital city of the new republic. When the construction of the Erie canal was agitated in 1817, it was thought that it would be necessary to engage an English engineer. However, the great work was finally planned and constructed by American engineers, self taught on the work. In fact, the Erie Canal was the first great school of American engineering. It trained an able corps of men, who, after its completion, designed and built many other great early American engineering works.

West Point was the only technical school in America in the opening quarter of the 19th century, and many of its graduates joined the ranks of civil engineers. However, engineering schools were soon established for the education of civil engineers. The Rensselaer Polytechnic Institute opened in 1824-1828, and half a century was the principal civil engineering school in the country. Union College, at Schenectady, New York, provided a civil engineering department in 1845. The Sheffield Scientific School at Yale, and the Lawrence Scientific School, at Harvard, opened in 1846 and 1847 respectively.

Throughout the 100 years from 1750 to 1850, progress along scientific lines was ever more and more rapid, and the period includes some of the greatest physicists and chemists the world has known. Of special interest to engineers, is the history of the gradual growth of the scientific knowledge of electricity.

During the 50 years from 1800 to 1850, general progress along engineering lines was especially rapid.

The great cities of Europe and America were now first adequately provided with water works and sewers, and sanitary engineering began to be placed on a scientific basis.

In bridge engineering, the first use of cast and wrought iron occurs at this time. Cast iron arches, suspension bridges and wrought iron tubular bridges were devised and constructed for spans up to 500 feet or more. Meanwhile there was a gradual development of the truss idea, which culminated, near the middle of the century, in a scientific analysis of the computation of bridge stresses, and began modern bridge engineering.

The pneumatic method of sinking foundations was developed. Many great tunnels, aqueducts and dams were built.

The substitution of steam for sail power made necessary the reconstruction of the world's shipping, harbors and docks. Iron began to supersede wood for ship building.

In America, the first great problem confronting engineers was to provide economical, rapid and efficient means of transportation from the interior of the continent to the coast, across the difficult barrier of the Allegheny Mountains. American engineers first successfully solved this problem by the construction of the Erie Canal, in the state of New York, from the Hudson River to Lake Erie. This canal was opened in 1825 and its great success helped inaugurate an era of canal building which lasted for a quarter of a century. The Pennsylvania canal system, with connecting railways, finally gave Philadelphia a traffic route to the Ohio River. The Chesapeake and Ohio Canal, however, never reached its proposed western terminus. In several other states, both east and west of the Alleghenies, extensive canal construction was carried on between 1825 and 1850.

During this same period, however, the railway proved itself the overwhelmingly successful rival of the canal, and between 1828 and 1850 a railway net of 8600 miles was constructed in the United States between the Atlantic Ocean and the Mississippi Valley. By 1850, the world's railway mileage had risen to 24,000.

12. G. **Outline of engineering since 1850.** In 1850, it seemed to engineers and to the world entirely improbable that the rate of progress shown by the great achievements of the preceding 100 years could be maintained in the future. In fact, however, that rate of progress has been vastly accelerated. It is no exaggeration to say that the world's engineering constructions since 1850 have exceeded in magnitude all prior achievement. Very much of this progress must be attributed to the organization and recognition of engineering as a real learned profession.

The development of engineering into a real profession was characterised, accelerated and in a large part accomplished by three agencies; namely, engineering education, engineering societies, and engineering literature. With a few exceptions, already mentioned, the development of these agencies has occurred since 1850.

Engineering Education. During the 25 years following 1850, the great polytechnical schools of Europe, especially of France, were still the mecca of American engineers, though American engineering schools were being established. A large number of such schools, including our own were organized about 1868 as the result of the Morrill Land Grant Law, which afforded national aid to the several states for technical education. Soon American engineering schools led the world. By 1901, over 16,000 engineering students were enrolled in the United States in 114 engineering schools. Abroad there had been a corresponding progress in technical education.

This great development of Engineering Education was due in large part to a great revolution, from 1850 to 1875, in general education. Prior to that period, the so called classical courses had attained the position almost of a fetich in higher education, and science was regarded as almost unworthy of even an inferior position in a college course. By the great revolution from 1850 to 1875, education in science and scientific research won its way to at least an equal standing with classics. The effect upon engineering, and indeed upon civilization in general, has been profoundly beneficial.

Engineering Societies. It has already been stated that the British Institution of Civil Engineers was organized in 1818. The Societe des Ingenieurs Civils de France was established in 1848; The American Society of Civil Engineers in 1852; The American Institute of Mining Engineers in 1871; The American Society of Mechanical Engineers in 1880; and the American Institute of Electrical Engineers in 1884. Every great nation has now its national engineering clubs and societies. The influence of engineering societies upon the profession has been profound.

Engineering literature. This was almost non existant in 1850, but has now become of very great volume and importance. Each particular branch of the profession has many books and periodicals devoted to its special lines of work.

Without them no engineer could keep in touch with the best practice in his work. These and other agencies have won for engineering a general recognition as a learned profession. Such recognition has already, in some states, been incorporated in statutes, regulating its practice, as in the cases of law and medicine.

During the sixty years which have elapsed since engineering became a real learned profession, progress in engineering achievement has been tremendously accelerated. It is true that by 1850 the **Steam Engine** had already conquered its greatest fields, and had reached a very high stage of development but since then we have seen the compounding, tripling and even quadrupling of the rates of expansion, accompanied by a very great increase in boiler pressures. We have also seen the development of the high speed engine, while in very recent years, the steam turbine has been brought into common use as an entirely new and efficient engine.

Meantime the **Gas Engine** has become a formidable rival of the steam engine. For light and powerful motors, always ready to start it has occupied practically the entire field. For larger power installations, the producer gas engine has been developed to an efficiency about twice as great as that of the steam engine.

In **Marine Engineering,** first iron, and then steel have taken the place of wood for constructing ships. Ever more powerful and efficient propelling machinery has been introduced. The size of ships has been increased again and again, until the largest vessels afloat in 1850 would appear mere pigmies if placed alongside the Carmania or the Lusitania of the present day.

Harbor Engineering has necessarily kept apace with marine engineering. Great channels have been dredged, or scoured out by jetties. Breakwaters have created artificial harbors, and made natural harbors safe. Money by the tens of millions of dollars has been expended upon docks, piers, warehouses and other harbor facitities.

In **Canal Engineering** the period since 1850 has seen the development of the ship canal. The Suez Canal, from the Mediterranean Sea to the Red Sea, was opened in 1869, and has greatly changed the main routes of the world's commerce. The Amsterdam Canal, in Holland, the Kuehl Canal, in Germany, the Manchester Canal, in England, and the Welland and St. Lawrence Canals in Canada have been notable achievements. The United States is now greatly enlarging the Erie Canal, and in the Panama Canal is successfully carrying out the greatest single piece of engineering work the world has ever undertaken.

The **Natural Waterways** of the world are now again securing development, which for a long time was checked by the overwhelming success of railways.

Water Power Engineering is now receiving a great impetus, owing to the enormous development of manufacturing, and to other great and rapidly increasing demands for power, togther with the development of long distance transmission by electricity.

Irrigation Engineering is undergoing a modern development on a very great scale, especially in the United States, which is once more giving it an importance corresponding to its ancient preeminence in Egypt and Chaldaea. It is now reclaiming territories which will add new states, almost nations, to modern civilization.

Drainage Engineering also is now adding vast tracts of reclaimed lands to the world's fertile areas, and strange to say, is even being found the necessary accompaniment of irrigation engineering in arid regions.

The excessive present day concentration of population in cities has created **Water Supply** problems of a magnitude never before dreamed. Aqueducts and pipe lines have attained lengths measured in hundreds of miles. Pumping plants are larger and more powerful than ever before. Purification methods

have been invented and developed on a scientific basis, and constructed on a very great scale. Above all, the advantages of water supply have been extended, since 1850, to practically all cities and to a very large proportion of villages.

Sewerage is the necessary accompaniment of public water supply engineering, and sewerage engineering has kept even pace with water supply engineering since 1850. Sewage disposal has become of vital importance. Sewage purification has almost entirely been the development of this period.

Highway Engineering, owing to the great expansion of railways, did not show very extensive development for many years after 1850. Of late, however, its great importance has received renewed recognition, and rapid advancement is now being made. The recent wide introduction of motor vehicles has brought new difficulties to overcome, while according possibilities of new conditions in rural life which may prove to be of very wide reaching effect.

Railway Development has been, in point of magnitude and vital importance, one of the greatest of engineering achievements since 1850. The world's railways increased from 24,000 miles in 1850, to 340,000 in 1887, and to 524,000, in 1902. Of this the United States had 202,000, and the mileage in this country had risen to 227,000 in 1907. In the United States, the years immediately following 1850 saw the railway net extended across the Mississippi Valley to the Missouri River. The great problem then became that of reaching the Pacific Coast, across the barriers of the Rocky and Sierra Navada mountains, and in spite of the great difficulties due to the wide expanse of wilderness desert which lay in the way. American engineers accomplished the first solution of this problem in 1869, when the opening of the Union and Central Pacific Railroads completed the first transcontinental railway. In America there are now many transcontinental lines along different parallels of latitude, and one has been constructed across South America by Chile and the Argentine Republic. A project has been put forward, and has received serious consideration, extending as far as preliminary surveys, for the construction of a Pan American railway, running north and south the length of the American Continent. Abroad, the Trans-Siberian Railway, 4000 miles in length opened in 1901, constitutes the world's longest railway. Engineers have constructed railway nets in every country of importance on the globe. Just now the Cape to Cairo Railway in Africa seems destined to accomplish a work in opening up the "Dark Continent" to civilization which will be comparable to the work of American railways in the settlement of the West. The important advances in railway engineering since 1850 have not, however, been confined principally to such wonderful achievements in new construction as we have here briefly outlined. In road beds, bridges, signals, brakes and other safety appliances, terminals, and especially in motive power, the achievements have been fully as remarkable.

Street Railways are almost entirely the development of the period since 1850. Beginning in New York City in 1831 with horse traction, they rapidly extended, after 1852, to all the principal cities of the world. Cable railways were introduced in San Francisco in 1875, and for several years were quite extensively used for very heavy traffic, or to climb very steep grades. Beginning in 1883, the electric railway started a development which within twenty years practically displaced all other motive power for street railways. The difficulties of operating surface railways on the crowded streets of large cities, led to the introduction of elevated railways in New York City in 1872, and of subways in London in 1860-1884. Both subways and elevated railways have been developed extensively in these and other great modern cities.

In **Tunnel Engineering,** though tunneling is of very ancient origin, and though especially important tunnel works had already been carried through in the twenty-five years preceding, the achievements since 1850 far eclipse all that had been accomplished previously. In America the Hoosac Tunnel, 4 3-4 miles long, built in 1854-1876 to afford New England a direct railway

outlet to Albany, was the precursor of many railway tunnels. In Europe, however, the Alphine tunnels were much greater undertakings. There have been four of these completed, betwen 1857 and 1906, the greatest and latest being the Simplon, 12 1-4 miles long. These give direct railway communication between Italy and France and Switzerland. During recent years, we have seen at New York tunnel engineering of the highest type in progress on a great scale, and a very difficult piece of such work is just completed at Detroit.

In **Bridge Engineering** the advance has been very rapid during the last sixty years. The years immediately following 1850 saw the rapid scientific development of bridge trusses, and their construction by the shops on an ever larger and larger scale. Many varieties of trusses have been devised and successfully applied to special conditions. The suspension type of bridge has been employed for long spans on a great scale. The Niagara Suspension Bridge in 1855, the Brooklyn Suspension Bridge, of 1595 feet span, in 1883, and the Williamsburg Bridge, also at New York City, of 1600 feet span, are notable examples. The suspension type has the advantage of not requiring false work during erection. The cantilever type of bridge has been developed as a substitute, preferred in many cases, for the suspension type. At Niagara, the second great railway bridge, completed in 1883, was a cantilever. The Forth Bridge, over the Firth of Forth near Edinburgh, in Scotland, the world's greatest bridge, is a cantilever structure. It was completed in 1890. There are two 1700 foot spans. The Quebec Bridge, which failed so disastrously, was a cantilever, and was to have had a span of 1800 feet. The Blackwell's Island Bridge, recently completed in New York City, is another notable cantilever. The steel arch has also been developed since 1850 as a design often preferred for great bridges. The Eads Bridge over the Mississippi at St. Louis in 1874, the Niagara Railway Arch in 1897, and the Garabit Arch in Southern France, built in 1884 by M. Eiffel, are famous examples. The American railway viaduct is another type of bridge developed since 1850. A notable example is the Boone Viaduct, a double track structure half a mile long and 180 feet high, carrying the Chicago & Northwestern Railway over the Des Moines River. The last sixty years have seen the substitution, first, of wrought iron for wood, in bridge construction, and second, of steel for wrought iron. We are now witnessing the extending use of reinforced concrete, and other types of permanent masonry, in place of steel in many cases for bridge construction.

Structural Engineering, as distinguished from bridge engineering, is mainly a development since 1850. Steel is applied on a very large scale to building and shop construction, to piers, and cargo handling machinery, head works for mines and scores of other uses requiring scientific design by the structural engineer. The steel skeleton type of building is a late development, as is also the use of tile fire proofing, and reinforced concrete floor, column and building construction.

Many of the developments of modern engineering have been due to the extensive concentration of population in cities, and the consequent creation of new engineering problems of vital importance. Hence **City Engineering** has had a rapid development in recent years. The city engineer needs to be competent to take charge of many lines of engineering work. Mention may be made of accurate surveying, the establishment of street grades, and of water supply, sewerage and paving. In paving, the period since 1850 has seen the introduction of asphalt, brick, creosoted blocks, bitulithic paving, and concrete, as new types of surface materials, and of concrete on a large scale for foundations, crossings and sidewalks.

Since 1850 **Mining Engineering** has accomplished much to make mining a more certain, more profitable, more pleasant and safer occupation, though very much still remains to be accomplished along these lines. New explosives, new drilling, excavating, transporting, hoisting, and separating apparatus have been devised and applied on an extensive scale. Electricity has been

made use of for light and power. Shafts have been sunk to greater depths, and levels driven over greater areas than were ever before possible. More efficient and more powerful pumping machinery has been installed, and great drainage tunnels, many miles in length, have been driven to remove drainage water by gravity. New and extremely ingenious and scientific methods and appliances for extracting the metals from the ore have been invented and applied. Magnetism has been used to concentrate low grade iron ores. The steam dredge has taken the place of the old placer miners to obtain the gold from the gravels of our western coast rivers. The period from 1848 to 1910 has witnessed successively the discovery of gold in California in 1848, and in Australia in 1851, of the Comstock Silver lode in Nevada in 1859, of diamonds in South Africa in 1860, of the gold mines of the Witwatersrand in South Africa in 1885, and of the discovery of gold in Alaska in 1896. Each of these discoveries has had a very great effect in bringing about the extension of civilization to before unknown and barbarous or savage countries.

Petroleum and natural gas are two practically new and extremely important mineral products which mining engineering has given the world since 1850.

Ceramic Engineering deals with all the silicate industries of which the making of brick, tile, pottery and other burned clay products, and the manufacture of cement, are the most familiar examples. The making of brick and pottery dates from prehistoric times, but only since 1850 has it been put on a scientific basis. Cement was known somewhat prior to 1850, but only since that date have its manufacture and use been developed on a large scale. Since 1880, especially, its use has been growing by leaps and bounds. Only within a few years have courses in Ceramic Engineering been offered in the schools.

The growing necessity for conservation of natural resources is now giving special importance to the scientific development of mining and ceramic engineering.

Metallurgical Engineering has marked another important landmark in the world's progress by the invention and successful development, in the period since 1850, of the electric furnace. By its aid, and that of other new scientific advances, metallurgy has given us many new metals and alloys. Probably the most noteworthy is aluminum, which has been manufactured on a successful commercial basis for the past twenty years. At any time some new cheap method of producing aluminum may be discovered, and may have the effect of making it the long heralded substitute for iron and steel for construction work. Electro metallurgy is a modern development of metallurgy, which seems to have most wonderful and almost limitless possibilities.

The metallurgy of **Iron and Steel** has made very great advance during the period that we are now considering. In 1856 to 1858 Sir Henry Bessemer made known and developed the Bessemer process of making steel, and thereby so reduced the cost that in 1882 the saving represented an annual total of $1,000,000,000 in England alone. About 1867 William Siemens successfully applied the principle of the regenerative gas furnace to the manufacture of steel, and hereby introduced the open hearth process. In 1878-9 Sidney Thomas and P. C. Gilchrest demonstrated and gave practical development to the "basic" method of removing the phosphorus, from highly phosphoric ores. Since 1850 blast furnaces have been growing larger and larger, and the use of labor saving devices and powerful machinery in connection with steel manufacture more extensive. Of very recent date is the actual use of the electric furnace for making steel, and also the production of extra fine grades of iron and steel. The special demand for extra fine grades of iron and steel has now become very great on account of the recently developed electrolytic theory of corrosion.

The demands for power have become so great, and the methods of developing power so scientific, that **Power Plant Engineering** requires special preparation and experience at the present time.

The same is true of **Factory Engineering.** Many modern factories cover scores of acres each with their buildings. The modern factory requires careful and scientific planning and supervision of operation, both as to the general design and as to each detail.

Manufactures and Arts have developed since 1850 as never before in the World's history. The old manufactures have been extended to undreamed of magnitudes. The myriad new inventions of each year require new development of manufactures. The scientific curiosities and luxuries of one decade become the most useful and powerful machines and the common necessities of life in the next.

Chemical Engineering has developed into a separate branch of the profession, with special courses of study in the engineering schools. This branch of engineering has in charge many manufactures of vital importance in connection with the necessities of life, besides being responsible for the manufacture of all chemicals, and chemicals are necessities in all the arts.

The recent enormously extensive development of the use of **Agricultural Machinery** on the farm, has made one man today the equivalent, in point of work done, of several men in 1850. This development besides greatly stimulating manufactures and commerce, directly affects the world's food supply in a most vital way. It has been a very important factor in the great movement of population into cities and towns.

Undoubtedly the most spectacular, and among the most useful engineering achievements since 1850, have been those directly connected with **Electricity.** Advance in knowledge of the actual nature of electricity has been slow. We are still ignorant of the real nature of this great agent which is so important in modern life. It is interesting to note that the latest ideas of matter surmise that its atoms may be composed of very small subdivisions, called electrons, each charged with, or composed of electricity, and that this is practically a return to the one fluid theory of Franklin, but with the idea that the fluid is negative rather than positive. The present day ideas of the nature of electricity are vitally connected with the latest ideas concerning the physical construction of matter. However, the main progress in our knowledge of electricity since 1850 has been in connection with its practical applications for the use and convenience of man. These practical applications have been made almost entirely during the period we are considering, though the scientific foundation work, which was their necessary precursor, had been in active progress for some time previous.

The credit for the **Electric Telegraph** is usually given mainly to S. F. B. Morse, whose work extended over many years. The date of 1844, when he first put into successful operation the telegraph line from Washington to Baltimore, is usually taken as that of the achievement of the electric telegraph, but most of the actual construction of telegraph lines has been carried out since 1850, and the early imperfect telegraph has been developed, by many improvements, into the perfect modern telegraph. The telegraph now covers the globe and forms an indispensable agency of life. The first Trans-Atlantic cable was laid in 1858, but was not fully successful. The second was completed in 1865. Of very recent date has been the development of **Wireless Telegraphy,** which is still going on so rapidly.

The ten years from 1875 to 1885 were perhaps the most notable of any which have yet elapsed in the history of **Electrical Engineering,** for they saw the practical development of the dynamo, the electric motor, the electric light, the electric railway and the telephone, together with the first establishment of separate courses of study in electrical engineering, and the formation of a national society of electrical engineers. These ten years may be said to have sufficed to establish electrical engineering as a separate branch of the engineering profession.

After the telegraph, the next successful achievement of electrical engineering was that of **Electric Power,** through the successful development of the dynamo and the electric motor for generating electricity and for reconverting

it into power. Though work had been progressing for several years previous, yet since 1880 progress has been especially rapid in this line, and, besides most efficient and powerful generating apparatus, and motors convenient and efficient for every service, has also included the development of transmission lines, by which electric power may now be transmitted economically for distances as great as 100 to 200 miles.

The development of electric power resulted in the immediate development of **Electric Lighting**, which had already been the subject of study and experiment for many years. First the arc light, as worked out by several men, and then the incandescent lamp of Edison, were speedily and successfully developed on a commercial scale after 1880. The introduction of electricity into the field of illumination, following the previous great development of gas illumination, after its invention near the close of the 18th century, did much to put this subject on a scientific basis, and now **Illumination Engineering** is coming to be recognized as a separate branch of engineering. Our own Iowa State College has just received the commendation of technical journals for being first to recognize the new branch of the profession in a departmental title, by the establishment of the department of Physics and Illuminating Engineering, with separate scientific work in illumination.

The **Electric Railway**, as already stated, was first successfully operated in 1883, and within 20 years practically displaced all other forms of traction for street railways. It has also had extensive development, which is still going on more and more rapidly every day, for interurban railways. It even seems quite possible that electricity may come to displace the steam locomotives on some of our trunk railways in the not distant future.

The **Telephone**, as a successful apparatus, is usually credited to Alexander Graham Bell, whose first great success was attained in 1876. Its use has extended over the entire world since that date, and the importance of the telephone in both city and country life can be hardly overestimated. **Wireless Telephony** is still in a somewhat more experimental stage than wireless telegraphy, but promises much for the near future.

Military Engineering has been almost entirely revolutionized since 1850 by many developments: Of the breech loader, the repeater and the automatic gun; of improvements in ammunition, including the fixed cartridge and smokeless powder; of modern high powered and quick firing artillery; of mines and torpedoes for defense and attack. To meet the attack of such weapons, steel armor has been applied to war ships, and again and again improved, and new methods of fortification have been devised for land defense. Most extensive use is made in modern military engineering of the telegraph, telephone, electric and steam power, of modern methods of transportation, of the latest improvements in sanitation, and in fact, broadly speaking, of all the great engineering advances of modern times.

Architecture has made its greatest modern achievements in designing and constructing a multitude of great buildings adapted to modern needs, constructed in many instances of new or comparatively new structural materials. Architecture has not as yet developed new styles of architecture suited to the new modern conditions. While the achievements of the architect have been therefore great, as regards quantity and magnitude, they have fallen far behind those of earlier ages in point of artistic achievement.

CHAPTER II.

ENGINEERING.

13. In Chapter I, after some introductory discussion, we made a brief summary survey of the entire History of Engineering. Chapter II will be devoted to a general discussion of engineering and its field.

14. **Definition of Engineering.** Many definitions of engineering have been proposed, several of which will be given in Article 18. By far the best and

most authoritative is the one which was incorporated in the charter of the British Institution of Civil Engineers. This definition will be adopted throughout these lectures. It is as follows:

Engineering is the art of directing the great sources of power in nature for the use and convenience of man.

Careful study of this definition and comparison of it with others has convinced the author of these lectures more and more that it is the best definition which has yet been proposed. In the original definition, the term Civil Engineering was used instead of Engineering, but in the progress of engineering since 1827 the profession has been subdivided, so that Civil Engineering has a more limited meaning now than formerly.

The above definition should have all the greater authority because of the fact that it was incorporated in the constitution of the first great engineering society, whose establishment, in 1818, marked, in itself, a decisive point in the change of engineering from a trade to a profession. The definition should be credited to Tredgold, one of that great group of British engineers who lived in the latter part of the 18th century and the early part of the 19th. In 1827 Mr. Tredgold was asked by the Council of the Society to "give a description of what a civil engineer is," to incorporate in a petition for a charter. In the charter of the Institution, the following words are added to those given above: "as the means of production and of traffic in states both for external and internal trade as applied in the construction of bridges, aquaducts, canals, river navigation and docks, for internal intercourse and exchange and in the construction and adaptation of machinery and the drainage of cities and towns." These added words really detract from the definition and serve to show how limited engineering was at that time, as compared with the present day.

A detailed study of the definition adopted above confirms the idea of its correctness and comprehensiveness.

For example, taking up the exact wording of the definition, we come, first, to the term "art." Engineering is an **art*** rather than a **science;** for although it is based directly upon the principles of physical science, it does not stop with the simple acquirement of the knowledge of those principles, but is devoted especially to the art of making actual applications of them in the affairs of civilization.

The definition goes on further to say that engineering is the art of "**directing**" the great sources of power in Nature for the use and convenience of man. Since the engineer must **direct** these great sources of power, it is necessary that he should be **qualified to direct,** and the use of this term in the definition requires engineering to be a **profession** rather than a **trade.** The craftsman of a trade must have skill to do the manual work of his trade, but need not have the comprehensive training necessary to direct. Not so with the engineer; he must be qualified to be a member of a real profession.

The **scope** of engineering is well indicated by the term "**the great sources of power in nature,**" and by the fact that these are to be directed "**for the use and convenience of man.**" The discussion of this scope, however, is worthy of a separate article.

15. **The Scope of Engineering.** As has already been stated, the scope of engineering is well indicated by the definition given in Article 14, namely that "Engineering is the art of directing *the great sources of power in Nature for the use and convenience of man.*" The term "*the great sources of power in Nature*" manifestly includes, *all those principles of science which: first, are vitally concerned with the action of forces on bodies; or, second, have especially to do with the properties of materials of construction.* The requirement that these principles of science are to be directed "*for the use and con-*

*Karslake, as quoted in Webster's Dictionary, has stated the distinction between an "art" and a "science" as follows: "In *science scimus ut sciamus* (we know that we may know); in *art, scimus ut producianus* (we know that we may produce). Therefore science and art may be said to be investigations of truth, but science inquires for the sake of knowledge, art for the sake of production."

venience of man" specifies the **field of engineering as including all useful applications of the above principles of science.**

The field of engineering, thus specified, is very broad and very fundamental to civilization. While engineering, being the art of directing these great sources of power in Nature, rather than simply of working in them, is far above the work of the artisan and the mechanic, yet it necessarily includes the work of all artisans and mechanics. It includes, for example, the work of the lowest savage who ever fashioned the rudest implement from stone or any other material, just as much as it includes the work of the highly skilled mechanician of the present day who builds a modern locomotive. It includes the earliest use of human and animal power, as well as the latest developments in steam and electricity. It includes the construction of the first rude hut, and of the latest forty story sky scraper. It includes every handicraft which has been developed by the human race, in so far as such handicraft may require the use of any physical material, or tool or implement of any description. It includes all manufactures, all transportation, all communication of intelligence by mechanical appliances. It also includes the work of scientists of all ages, in so far as discoveries of science have resulted at all in the useful applications of the laws of forces, the use of physical materials of construction, or the use of tools or implements of any description, or any other use of the principles of mechanics for the benefit of man. The field of engineering is, therefore, very broad, and, while engineering itself has not been recognized as a profession until recent years, yet its history must extend back to prehistoric times.

16. **Derivation of the words Engine, Engineer, and Engineering.** It will be of interest and value to trace the origin of the words, engine, engineer, and engineering. Clear statements of these derivations will be found in the Century and Webster's Dictionaries, as well as elsewhere. The editions here quoted are those of 1889 and 1890. The best discussion of the origin of the name of our profession, however, will be found in the life of Sir William Fairbairn, written by the late Dr. William Pole, Secretary of the British Institution of Civil Engineers, abridged and quoted in the appendix to the President's address of James Charles Inglis, Nov. 2, 1909. See Proceedings of the Institute of Civil Engineers, Vol. 179, pages 16, 17 and 18.

The above abridgement gives so clear and concise a discussion of the subject that it will be inserted here verbatim.

"The term **engineer,** as defining an occupation, is an old one; but it was originally applied only to persons in the military profession, and does not appear to have been used by civilians until the middle of the last (i. e. eighteenth) century.

"The root of both the words, Engineer and Engine, is found in the Sanscrit *jan*, to be born, from which came the Greek form γεν, and the Latin *gen*, the latter being embodied in the old verb *genere*, with its compound, *ingenere* (changed into *ingignere*), to implant by birth, and in the latter substantive *ingenium*, an innate or natural quality.

"The old Latin verbs, *genere* and *ingenere*, gave rise to a French form, also a verb, *s'ingénier*. This is of great antiquity, and from its comprehensive and useful meaning it has continued in use down to the present time, being found continually in modern French writings. The import of it has nothing whatever to do with engines or machines, but is purely psychological. It is given in Littre's great French dictionary:

Chercher dans son génie, dans son esprit, quelque moyen pour réussir.

"Now all authorities, including our own great Lexicographer, agree that this word is the true origin of the word **engineer,** and thus we arrive at the interesting and certainly little-known fact that an Engineer is, according to the strict derivation of the term, not necessarily a person who has to do with engines, but anyone who seeks in his mind; who sets his mental power in action, in order to discover or devise some means of succeeding in a difficult task he may have to perform.

"It would be impossible to give a nobler or more appropriate description than this of the manner in which our greatest engineering works have been produced, or the nature of the qualifications by which the greatest men in the profession have acquired their renown.

"The use of the word in England is almost as old as on the Continent; for in the wardrobe account of King Edward I, A. D. 1300, occur expenses paid to several engineers for military artificers' work; and in 1344 it is stated that 321 artificers and engineers were borne on the books of the Ordnance.

Coming down to Queen Elizabeth's time, we find the term used by Shakspere. Writing about 1602, he makes Hamlet say (Second Quarto, 1604):

"For 'tis the sport to have the enginer
Hoist with his owne petar, an 't shall goe hard
But I will delue one yard belowe their mines,
And blowe them at the Moone.

"A few years later, in 'Troilus and Cressida,' Thersites is made to say (Folio, 1623):

"Then there's *Achilles*, a rare Enginer. If
Troy be not taken till these two undermine it,
The walls will stand till they fall of themselues

"But there is another very remarkable passage where Shakspere uses the word, not in the sense of director of engines, but with the meaning before mentioned, '*Chercher dans son génie.*' It is in Othello (Folio, 1623):

"He hath atchieu'd a Maid
That paragons description, and wilde Fame;
One that excels the quirkes of Blazoning pens,
And in th' essentiall Vesture of Creation,
Do 's tyre the Ingeniuer.

"It is remarkable too that in this place there is an approximation to the French original word *ingénieur*.

"In Cotgrave's French and English Dictionary 1611 the word *ingénieur* is translated 'engineer, engine-maker, fortifier.'

"An Engineer, therefore, was, according to the most common acceptation of the term, a person in military service, whose business it was, not only to direct warlike engines or weapons (a duty transferred at a later period to the artillery officer), but to undertake the design and construction of fortifications, siege-works, roads, bridges, buildings, machinery, and all other works for military service which required knowledge, experience, and skill in the arts of construction.

"Down to a recent period, the title Engineer was never applied to the constructors of similar works in civil life; yet the construction of such works generally has existed from time immemorial.

"From the nature of the engineering works carried out by the Egyptians, Greeks and Romans, we may be fully convinced that they were designed by men well acquainted with the philosophical principles current in their era; and as a matter of practice, how excellently they were done is testified by the manner in which they have stood the ravages of time. We may indeed doubt whether there are many engineering works of the present day which will, at the end of thousands of years, make as favorable an appearance as those of the ancients do now.

"About the twelfth century, attention became strongly directed in France to the internal communications of the country, and an association was formed under the name of the "Freres Pontiers" (Brethren of the Bridge), with the object of building bridges wherever rivers were dangerous or difficult to ford. They extended branches over all parts of Northern Europe, and executed great numbers of important works, some of which still exist: as for example, the Old Bridge at Lyons, and another celebrated one over the Rhone at Saint Esprit, nearly half a mile long. The first stone London Bridge was also erected by them. This body is perhaps the earliest example of a definite, though small class of persons, expressly devoting themselves to civil works of an engineering character, and they might well have called themselves a Society of Civil Engineers had the name been in existence at that period.

"It was not till some centuries later that the constructors of large civil works became such an important class as to require a special distinguishing technical name, and, just as the Freres Pontiers owed their incorporation to the wants of the roads of France, so the later and more important body were brought into existence by the needs of the rivers of Italy.

"When the Italian Republics, in the twelfth century, revived the arts and sciences, they took measures to regulate and open the navigation by rivers long neglected, particularly on the Po and the Mincio. Three centuries later, Leonardo da Vinci added to his already great fame by the promotion of extensive works of navigation, and especially by his introduction of locks (invented by the brothers Viterbo in 1481) on the Milanese canals.

"About the commencement of the seventeenth century, the great rivers in the North of Italy appear to have relapsed into a very bad state, and the consequence was felt in disastrous inundations. The inhabitants of the districts became alarmed, and the most learned scientific men of the day were consulted as to how the evils might be remedied. To this impulse we owe a series of valuable theoretical and experimental studies, which lasted for a century and a half, and ultimately formed a thorough basis for hydraulic science and practice.

"The knowledge thus acquired spread rapidly throughout Europe, and gave a great impulse to hydraulic operations. But now arose a want of competent men to execute them. The architects, who had formerly undertaken constructive works generally, found these new studies somewhat foreign to their own business, and were moreover already well occupied in their more legitimate employment. Hence a new class of practitioners was called for, who should devote their attention to hydraulic constructions, with all their necessary mechanical arrangements; and with these soon became associated constructive works which did not embody the artistic element, and might therefore be fairly dissociated from the profession of the architect. Thus the new class of men undertook to design not only river and hydraulic works, but roads, bridges, docks, harbours, mills, and machinery, and massive buildings generally. Such a class required a new name, and this was easily found. It could not fail to be noticed that the kind of work undertaken by these practitioners was exactly analogous to that allotted to the "Engineers" of the military service, and the new profession therefore adopted the same title, prefixing, however, the word "Civil," to indicate that they were civilians, and so to distinguish them from their military brethren.

"Hence the origin of the term **civil engineer**, its true meaning being a person who devotes himself to occupations of the kind originally practiced by military engineers, but who belongs to the civil and not to the military community.

"It is probable that Smeaton was the first civil practitioner (if not absolutely, at least in England), who formally denominated himself an "Engineer." A report he made, dated July 11, 1761, on a canal in Staffordshire, is entitled:

"Report by John Smeaton, Engineer, concerning the practicability, etc., of a navigable canal.....as projected by Mr. James Brindley, Engineer.

"He here awards the same title to his coadjutor, but there is no evidence that Brindley himself had previously used the term.

"Smeaton had also the good sense to see the difficulty that this appellation might place him in, as pretending to assume a title hitherto only belonging to military men, and it was he who accordingly first adopted the prefix "Civil" to avoid all appearance of collision. He, however, only adopted the compound term on state occasions, usually styling himself simply "Engineer."

"It is pleasant to think that the name, now become so common to denote a civil practitioner in engineering work, was originated and bestowed upon the profession by one of its members so thoroughly accomplished and so highly esteemed."

The Century Dictionary gives the following meaning for the word "engine," the definitions being the same, practically, as those given in Webster's. 1. Anything of natural ability; ingenuity; craft; skill. ("He does't by en-

gine and devices''—Ben Johnson). 2. An artificial device or contrivance; a skilfully devised plan or method; a subtle artifice. (''Therefore this craftie engine did he frame.''—Spencer). 3. An instrumental agent or agency of any kind; anything used to effect a purpose; an instrumentality. 4. An apparatus for producing some mechanical effect, especially a skilled mechanical contrivance; used in a very general way.

The three meanings given by Webster's Dictionary to the word ''engineer'' are as follows: 1. A person skilled in the principles and practice of any branch of engineering. 2. One who manages an engine, particularly a steam engine; an engine driver. 3. One who carries through an enterprise by skillful or artificial contrivances; an efficient manager.

It is unnecessary to give a separate discussion to the word ''engineering.''

In this connection it may be noted that more or less confusion has arisen from the double use of the word ''engineer'' to indicate, first, a member of the engineering profession, and second, an engine driver, the latter being simply a highly skilled mechanic. At various times it has been proposed to do away with the double use of the word, but custom in this particular is entirely too strong to be overcome by the wishes of the engineering profession.

17. **The Meaning of the Word ''Engineering'' as Indicated by the Derivation of the Word ''Engine.''** The outline of the derivation of the words ''engine,'' ''engineer,'' and ''engineering,'' given in Article 16, may help to give a correct idea of the inherent meaning of the terms.

First. They involve the ideas of ability, ingenuity and genius as essential features of the qualifications of the engineer.

Second. They involve the idea of the use in some engineering work of an engine, that is, of any sort of mechanical contrivance.

Engineers may feel proud that the very name of their profession signifies unusual skill and training as essential requisites of the profession. In homely words, this principle has been stated as follows: ''An engineer is a man who can do with one dollar what the ordinary man might effect with two dollars.''

18. **Encyclopedia and Dictionary Definitions of Engineering.** It will be of interest to study other definitions of engineering than the one adopted in Article 14, and especially such definitions as have been published in standard reference books. The definitions given in such books have been carefully worded to show the best usage at the time they were published, and while they may be under the great disadvantage of not having been criticised by a member of the engineering profession, yet much of interest concerning the engineering profession can be learned from them.

Encyclopedia Britannica Definition, Edition of 1855. In this early edition of the Encyclopedia Britannica, we have the following definitions:

''Engineer properly signifies a person who is employed in devising and constructing engines or machines and in directing their applications.'' ''Military Engineer is an officer whose business it is to delineate plans and to direct the formation of military works and to regulate attacks and defenses.'' ''Civil Engineer is one who applies the principles of mechanical and physical philosophy to the construction of the machines and public works by which the arts and conditions of civil life are rendered more efficient, extensive and secure.'' From the above definitions, we may infer that in 1855 only two branches of the engineering profession were recognized, namely, military and civil engineering.

Encyclopedia Britannica Definition, Edition of 1876. In this later edition we have the following definitions:

Engineering: ''The art of designing and constructing works.'' The following branches are recognized in the definition, each including special lines of work, as follows: Civil Engineering—canals, river navigation, harbors, docks, roads, bridges, railways, lighthouses, water supply, irrigation, sewerage, gas supply, telegraphs, etc. Mechanical Engineering—machinery, mill work, steam engines, iron ship building, agricultural implements, etc. Mining Engineering—working and raising of coal, iron, lead, copper and other minerals. Military Engineering—fortifications, gunnery, artillery, telegraphy, etc., for war.

Century Dictionary Definitions, Edition of 1889:

Engineering: "The art of constructing or using engines or machines; the art of constructing civil or military works which require an especial knowledge or use of machinery or principles of mechanics." In connection with this definition, mention is made of civil engineering, electrical engineering, hydraulic engineering, mechanical or dynamic engineering, mining engineering, naval engineering and military engineering.

From the above definitions we can readily trace the gradual development of engineering from the years 1855 to 1889. In 1855, manifestly, there were only two branches, namely military and civil engineering, while by 1889 the profession had been subdivided into all the principal branches at present recognized.

19. **Definition of Architecture.** Since prehistoric times, architecture has had a very intimate connection with engineering, and it is therefore desirable that the exact meaning of the term architecture and the exact relationship of architecture to engineering should receive careful consideration.

The word "architecture" comes from a Greek word meaning *chief artificer, master builder.*

The *Webster Dictionary definition of architecture* is as follows: "The art or science of building; especially the art of building houses, churches, bridges and other structures for the purposes of civil life; often called civil architecture. 2. Method or style of building; characterized by certain peculiarities of structure, ornamentation, etc. 3. Construction in a very general sense: frame or structure; workmanship."

According to this general definition, then, architecture originally meant simply the art of building.

Of later years an added meaning has been given to the term, when used as the name of a profession, and this later meaning has well been stated in the *Encyclopedia Britannica Definition, Edition of 1878*, as follows:

Architecture "is the art of building according to principles which are determined, not merely by the ends the edifice is intended to serve, but by considerations of beauty and harmony. It cannot be defined as the art of building, simply, or even of building well. The end of building, as such, is convenience, use, irrespective of appearance, and the employment of materials to this end is regulated by the mechanical principles of constructive art. The end of architecture, on the other hand, is so to arrange the plan, masses and enrichment of the structure as to impart to it interest, beauty, grandeur, unity and power."

This definition very clearly states one of the prime requisites of architecture as a profession, namely, that the design shall be in accord with the best artistic principles, and not merely such as to serve the end of utility.

20. **The Relation of Architecture to Engineering.** Study of the above definitions will indicate that to some extent architecture and engineering overlap.

Engineering includes all use of mechanical principles, and these are absolutely necessary in the art of building, hence, engineering is necessarily a part of architecture. Also architecture includes essentially the application of artistic principles to the design of structures, while such application of artistic principles is not essential to engineering. In this sense, therefore, architecture, is not necessarily included under engineering.

On the other hand, engineering includes many sorts of construction not included under the general head of architecture, and includes many uses of mechanical principles and appliances which could hardly be considered as constructive. Engineering is, therefore, a broader term than architecture, and includes architecture as one out of many applications of mechanical principles and contrivances.

For thousands upon thousands of years, beginning with prehistoric times and extending down to within a very recent period, there was practically no distinction between architecture and engineering. For example, in an ancient Latin work on architecture by Vitruvius, written in the time of the Roman

Empire, there are chapters on Water Supply, and Machines, which fact shows that these features of present engineering work were considered at that time distinctly within the province of architecture.

In fact during the early history of mankind the construction of great buildings and monuments overshadowed in importance, in public estimation, the applications of mechanical science for the use and convenience of man. Hence, naturally, the work of the engineer was included, in a sub-ordinate capacity, in that of the architect. Only a few hundred years since, even the hydraulic engineer was called an "hydraulic architect."

At the present day, owing to the great development of science and its multitudinous applications in modern civilization, the profession of engineering has grown to be a much greater profession, in point of numbers, at least, than that of architecture. In 1901-2 there were 16,433 engineering students enrolled in the United States, and only 386 architectural students. We now have engineering as a separate profession from architecture, and engineering itself has grown so large as to be subdivided into many branches.

In fact, at the present time, as it seems to the author of these lectures, too wide separation has been made between architecture and engineering. On the one hand we have the architectural student, given a comparatively thorough training in art, but with only a smattering of engineering training. On the other hand we have the engineer, trained almost entirely along utilitarian lines, with no instruction in the artistic principles of design. A double misfortune has resulted.

On the one hand the architect, no matter what his training along artistic lines, can never make the best artistic use of the materials of construction until he is thoroughly master of their engineering principles and of all the engineering principles which are involved in their use. We cannot expect a new style of architecture, suited to the conditions of modern times until the architect has, first of all, become absolute master of the materials and mechanical principles upon which his work must be based, nor until he has become imbued with much of the true spirit of our modern industrial civilization.

The wider use of structural steel and of reinforced concrete in the building of structures, for example, have introduced new principles of constructing, to which the architectural styles which were developed for the stone columns of the Greeks and the masonry arches of the Romans and medieval Europeans are illy suited.

Again, the purposes of the great structures required for the commerce, the manufactures, the educational institutions, the scientific museums and the other great activities of modern civilization, which is so fundamentally based on science and technology, cannot be adequately expressed by those styles of architecture which represent the ideals of ancient and medieval peoples. Even the religious edifices and the governmental buildings of modern times should express to the eye the new ideals of progressive christianity, the new aspirations of intelligent democracy.

The modern architectural profession should be able to develop new styles of architecture to suit modern conditions. It is true that the laws and principles of proportion, harmony, and color and the other principles of art, are fixed and unchangeable, just as much as physical laws, but the application of the laws and principles of art to new materials of construction, and to new purposes of structures, requires new principles of design, to secure the best artistic results. The architect should be given thorough training, therefore, in engineering lines.

It is equaly true that the engineer needs some training in artistic principles of design, for there is no reason why utilitarian structures should not be designed with some reference to their appearance. It will often be found that no additional expense is involved in changing an ugly design into one which is pleasing to the eye. In the case of important engineering structures, it is undoubtedly true that an architect should be associated with the engineer in charge, in order that the best results may be secured, both as to utility and artistic appearance. The engineer needs some training along artistic lines, to make him even aware of the need for the services of the architect.

Similiarly, an architect should have an engineer associated with him in the design of important architectural structures, to insure the use of correct engineering principles of design.

21. **Major Branches of Engineering.** As has already been indicated in article 18, there were only two branches of engineering until a very recent time, namely, military and civil engineering. This was true until about 1870. Up to that time, civil engineering was a very broad term, including, all branches of the profession except those concerned directly with the military art. At about 1870, a subdivision of civil engineering was made into three branches namely, civil engineering, mechanical engineering and mining engineering; and at about 1885 electrical engineering was added, as a fourth branch of what was formerly called civil engineering. At the present time, therefore, there are five major branches of the profession, namely, military engineering, civil engineering, mechanical engineering, mining engineering, and electrical engineering. There are many subdivisions of these major branches.

22. **Military Engineering.** Military engineering is that branch of the engineering profession which has to do with all applications of forces and mechanical laws, and of all materials of construction, to the art of mechanical laws, and of all materials of construction, to the art of war, whether on land or on sea. It includes fortifications, gunnery, artillery, armor, mines, torpedoes, warships, transportation, communication, etc.

23. **Civil Engineering.**. The term civil engineering is given three different meanings at the present time:

First, in its broadest meaning, the term civil engineering includes all branches of engineering except military. This was the original meaning, the word "civil" being used in contradistinction to "military."

Second, in its narrowest sense, civil engineering includes only fixed structures, such as bridges, highways, docks, etc.

Third, in the commonly accepted meaning, civil engineering includes all branches of engineering except military engineering, mechanical engineering, mining engineering and electrical engineering. It is this meaning which will be adopted throughout these lectures. This definition of civil engineering has naturally resulted from the historic development of engineering, by the differentation from time to time of separate branches from what was originally designated as civil engineering.

In the accepted meaning, as stated above, civil engineering is a broader term than either mechanical, electrical or mining engineering. Each of these branches is restricted to some special lines of closely related work. Civil engineering, on the other hand, includes many lines of work which are not very closely related to each other.

A prominent civil engineer of the present time, J. A. L. Waddell of Kansas City, has stated* that the branches of civil engineering include "The design and construction of bridges; tunnelling, retaining walls, sea walls, and other heavy masonry; viaducts; wharves; piers; docks, river improvement; harbors and water ways; water supply; sewerage; filtration; treatment of refuse; surveying; canals; irrigation works; dams; geodetic work; surveying; railways, both steam and electric; gas works; manufacturing of power, steam, electric, hydraulic and gaseous; general design and construction of cranes; cable ways; breakers and other mining structures; the heavier structural features of office building and other large buildings that carry loads, the general problems of transportation, quarrying and handling of heavy materials; all designing and construction of a similiar nature." Some question must be raised as to whether all the above branches enumerated by Mr. Waddell should be included under the head of civil engineering. Special objection might be raised as to the general inclusion of manufacturing plants, which many would place under the head of mechanical and electrical engi-

*In an address at the International Congress of Arts and Science at the St. Louis Exposition, Sept. 21, 1904.

neering, and of breakers, and other mining structures, and the general problems of quarrying which many would place under the head of mining engineering.

24. **Mechanical Engineering.** Mechanical engineering is that branch of the engineering profession which has to deal especially with machinery. As it deals with moving apparatus, it is sometimes designated as dynamic engineering.

Dean G. W. Bissell of the Michigan Agricultural College, Lansing, Michigan, has suggested the following branches of mechanical engineering.

Steam engineering, including the design of steam power plants; heating and ventilating engineering ;railway motive power engineering; factory engineering; gas engineering, including light, fuel and power; marine engineering; chemical engineering, in part: agricultural engineering, in part.

Mr. J. A. L. Waddell includes under the head of mechanical engineering the following: "The design and construction of steam engines, machine tools, locomotives, hoisting and conveying machinery, cranes of usual type, rolling mill machinery, blast furnace machinery, and in fact all machinery which is designed for purely manufacturing purposes."

Since the field of mechanical engineering includes in its widest sense all machinery its field is very broad and important. It is hardly possible to exaggerate the greatness of opportunities along the lines of mechanical engineering in these modern days.

25. **Electrical Engineering.** Electrical engineering is that branch of the engineering profession which has to do with application of electricity.

Electrical engineering is the youngest of the major branches of engineering. Its developments and achievements have been in many respects, among the most remarkable of modern civilization.

Its general nature is well indicated by the following *definition from the Century Dictionary*, published in 1889. "*Electrical Engineering* is the science and art of utilizing electricity in the production of light, heat, and motive power in the transmission and distribution of energy, and in its application to a great variety of metallurgical and other purposes. It also includes the science and art of the erection and maintenance of the telegraph, of cable lines, and of electric railway signals."

Professor Fish has enumerated the following special branches of electrical engineering: Electric railways; electric light and illumination; long distance electrical transmission; electric machine design; electric power station design; storage battery engineering; telegraphy; telephony; electro-chemistry; electrometallurgy.

26. **Mining Engineering.** Mining engineering is that branch of the engineering profession which has to do especially with the mining and quarrying of ores, building materials, and other mineral products of the earth, and their transformation into the forms in which they must be used by other branches of the engineering profession.

Mining engineering is a branch of the profession which is fundamental to all the other branches, since it supplies them with the materials of construction. Civil engineers, for example, could do nothing without the materials used for structures; mechanical engineers, without iron and steel for their machines; electrical engineers, without copper for electrical conductors.

Mining engineering includes the following branches: Underground mining work, including the construction of shafts and drifts for transportation and hoisting of ores, drainage of mines, etc.; roasting; milling; stamping and concentration of ores; disposal of mine refuse; quarrying of building materials; metallurgy of iron, steel and other metals; manufacture of cement; manufacture of clay products; etc., etc.

The mining and manufacture of clay products, sand, lime, brick and cement are at present grouped under the general head of CERAMICS.

27. **The Interdependence of the Various Branches of Engineering.** It must be apparent from the above discussions that all the various branches of

engineering are closely interdependent. Attention has already been called to the importance of mining engineering to all the other branches, in supplying them with materials for their work; and mining engineering, itself would be useless without the roads and highways, the railways, canals and bridges of civil engineering to enable transportation of its products to all portions of the earth. Nor could mining be properly carried on in these days without the aid of many machines and electrical contrivances which have been constructed by mechanical and electrical engineers.

Civil engineering and mechanical engineering are inter-related at many points. For example, water supply pumping machinery, cast iron pipes, hydrants, valves, power plants for pumping stations, hydraulic plants for generating power, steam railways, and many other engineering constructions which require both fixed structures and machinery, are instances in which the two professions meet.

Electrical engineering and mechanical engineering have especially close relationship. Both deal more especially with machines, the distinction being that the electrical engineer has to do only with machines which make a direct application of electricity. The close relationship of mechanical engineering and electrical engineering is shown by the great similarity of the courses of study in these lines in all the best engineering schools.

Members of the different branches of the engineering profession should recognize their extensive interdependence, and should be above all petty jealousies of each other. They should in all cases consider themselves as members of the same great profession, bound to each other by the usual professional ties.

28. **The Place of Engineering in the World's Economy.** Modern civilization is a very complex development. Doubtless in the prehistoric past, individual men were largely independent of their neighbors, but in modern society each man is dependent for the necessities of his daily life upon the systematic efforts of many others. In his very home may be found, for example: Metals from mines thousands of miles distant; lumber from a forest half a continent away; cement from the mills of one state; stucco from the quarries of another.

From far and wide, over a large portion of the world's surface, materials have been gathered which have been used to build and furnish his habitation. His daily food comes from all over the world. His reading demands the best intellectual efforts of thousands of men scattered over the entire globe. Men are dependent upon one another as never before.

Such a complex society requires for its activities a multitude of agencies to carry on this work systematically. The various professions may be considered as such agencies. Each is the creation of society, and each is bound by certain rules of conduct which society has imposed upon it.

The engineer of the present day claims a prominent place among the learned professions. As modern civilization is especially distinguished by its use of the achievements of science, so engineering may be considered the profession especially characteristic of modern society. In primitive times it was possible for each member of society to acquire for himself the knowledge which was necessary for his use of such sources of power in nature as he could command, but now the degree of technical skill required to utilize the vast sources of power placed at our disposal by science is entirely beyond the reach of the ordinary individual. Society must therefore trust itself to a body of skilled professional men.

Every inhabitant of a great city, for example, is dependent upon the skill and fidelity of engineers for the ability to take so much as a single drink of water in safety. Negligence on the part of the engineers in charge of the water supply would at once produce a fearful epidemic.

The steam engine would be an engine of destruction were it not for the skilled mechanical engineer. Electricity, which has been brought into nearly every modern home, would deal death rather than render service had it not been subdued by engineers.

It would be hard to exaggerate the importance of engineering in modern civilization, and yet the engineer must be regarded as simply the agent of society. It is a common impression that although the services of the engineer are especially necessary in the development of a new country, yet when that country is once settled and developed the necessity for his services may be at an end. The opposite is true. The greater the development of civilization the greater the number of engineers required to do its work. Thousands of engineers are required in the west today where one was needed when its settlement began, and this is the increasing tendency of the times. Not only does the number of engineers increase owing to growth of population; but the percentage of engineers required also; so that the total number of engineers necessary to do the world's work increases in a geometrical ratio.

In the past the prominence of the engineer's work has been mainly in the line of *physical* achievement. At the present time new fields of *intellectual* opportunity seem to be opening before him. In the past the world has made use of its resources without paying the slightest attention to the future. At the present, regard must be had to conservation with a view to maintaining our great natural resources undiminished for posterity. Hence the technical skill of the engineer is now required in directing broad policies of government. It may seem absurd to dream of a time when one qualification for any public office may be technical skill, yet either our public officers of the future must have such skill, or engineers must constitute their closest and most valued advisors.

In the activities of the commercial and the manufacturing world, also more the need becomes insistent for men with the technical skill and knowledge of the engineer.

There has arisen as characteristic of the time a demand for broader training for the engineer. More and more it is coming to be realized that the mere possession of technical skill is not sufficient for an engineer of the highest type. He must be a broad, all around man, capable of applying his technical knowledge to the great problems of modern life.

CHAPTER III.

THE ENGINEER.

29. **Engineering and the Engineer.** Chapter two has been devoted to a discussion of engineering. Chapter three will have for its subject the engineer.

It must be apparent that the ability, the character, the training, the faithfulness, the enthusiasm and the standing of the men who pursue it are all important to the profession of engineering. However important may be its place in the world's economy, however indispensable may be its service to society, engineering would fail as an agent of civilization were it not for the high character and qualifications of the engineer. It is fitting and essential, therefore, that attention should be diverted, for a moment, from engineering as a profession, and devoted to the study of the engineer as an individual.

30. **The Fundamental Qualifications of the Engineer.** The fundamental qualifications of the engineer may briefly be enumerated as follows:

First, and most fundamental and important, he must have honesty, morality and the highest character;—*second*, he must have good judgment, good sense, energy, persistency, confidence, ability;—*third*, he must have the best technical training;—*fourth*, he must have extensive experience in the practice of his profession in addition to technical training;—*fifth*, he must keep up with the times by constant reading of technical literature, by membership in technical societies and intercourse with his fellow engineers;—*sixth*, he must be a broad well rounded man, and a good citizen.

These fundamental qualifications are not widely different from those of any great calling. They are worthy of separate detailed discussion.

31. **Honesty, Morality and High Character Indispensable Qaulifications of the Engineer.** As was stated in Article 30, honesty, morality and high char-

acter are the most fundamental of all the qualifications of the engineer. Without these there is absolutely no hope of his success in the profession. As Engineering News has stated, "The best asset the engineering profession has is its reputation for honesty. It is the duty of every engineer to preserve that reputation unsullied."

At the dedication of the Engineering Hall of the Iowa State College, in 1903, Mr. M. J. Riggs, superintendent of the Toledo branch of the shops of the American Bridge Company, delivered an address upon "The Making of an Engineer," from which the following pertinent remarks will be quoted, as showing the unanimous opinion of the leaders of the engineering profession as to the indispensable nature of honestly, morality and high character as qualifications of the engineer.

"If the engineer is to carry on successfully this great work he must be a first-class man, he must be honest. He deals with forces and principles which are unvarying and which of themselves tend to make him honest. He must be honest to himself, to his work. Any violation of the well known laws of nature will certainly make itself known and result in expense and disaster.

"He must be honest with his clients and employer, since he is put in charge of great interests, both financial and material, and if he is to have the confidence of those for whom he works he can only have it by strict integrity and attention to business.

"There is probably no place in any profession or business for the dishonest man, but of all the professions of which I know that of engineering has the least room for such men. On the whole, I believe engineers as a class are usually honest and honorable. I have known a few of the opposite kind and have never known one to succeed and maintain any position whatever."

And then, after some lengthy discussion of other qualifications, again: "Lastly, the engineer should be a good man. The qualities I have outlined will necessarily make him a man of power, of strength, and of influence, not only with the men with whom he works, but also in the community in which he lives. These qualities cannot but make him a leader in social and public life.

"A man with all this inherent strength has no business to lessen it and curtail his usefulness and influence by not being a man of good morals, and by not using this strength to build up and help other men. There is no reason why the engineer should be blind on the moral side, and every reason why he should be the opposite. I have little patience with the cob pipe, cigarette smoking, beer drinking engineer, and I believe no one else has, and I also believe that the brightest man cannot succeed in the engineering profession who is not letting his influence for right be felt by his associates, friends and neighbors."

The author of these lectures desires to state as strongly as possible his belief in the fundamental importance of honesty, morality and high character as absolutely indispensable qualities for the engineer. He feels that of late years too little emphasis has been laid upon this subject. He believes that engineering educators have made a mistake in simply assuming these qualifications in the men whom they are training, and that they owe to the engineering profession the duty of inculcating these qualifications in the men they are training, in season and out of season, by word, and by precept, at every opportunity.

32. **Good judgment and strong common sense, energy, persistency, confidence and ability necessary qualifications of the engineer.** The engineer must have *good judgment and strong common sense*. It is absolutely impossible for him to lay down set rules, upon which he can always rely to decide the many questions which arise in his work. The problems which he must solve are not, like those which he has studied in mathematics, capable of exact solution according to unvarying theories. He must be able to weigh evidence, and sift the truth from a mass of apparently conflicting data. He must be able to obtain a correct perspective, and grasp essential general principles.

An employer of engineering graduates has said that the men he wants are not those who are simply capable of performing a task when they have been told how to do it, and then are watched to see that they do it correctly. The men he wants in his work are those of good judgment, and strong common sense, who,

from general instructions only, can successfully solve the problems which are given to them, and successfully meet all conditions and overcome all difficulties which arise in their work. The qualities of good judgment and common sense are often meant when the statement is made that the engineer should be "practical."

Energy is another of the important qualifications of the engineer. Mr. Riggs, already quoted, says:

"The engineer must be energetic. His work is to get things done. He receives his pay and holds his position because men with means want to invest it with the idea of prompt returns. There certainly is no place in the engineering world for the lazy man. It is not how long will it take, but how quickly can it be done, and how well; not how little can be accomplished today, but how much; not half way service, but the very best that is in him."

The engineer must have *persistency,* for often the obstacles which he meets seem unsurmountable, and it then becomes necessary to carry the work through by sheer force of will. There is always some way by which it can be accomplished. What the employer of the engineer, and what the public want, is not a report as to why a certain task could not be accomplished, but a statement showing how the obstacles were overcome. The difficulties in the way of performance should be reported as a guide to other engineers in attacking the same problem, and not as an excuse for its non solution.

The engineer needs *self confidence,* for the timid hesitating man, doubtful of himself, is not fitted for the strenuous duties of an engineer's life. On the other hand, the engineer should not be egotistic, but should receive suggestions from his subordinates and others with courtesy, and give such suggestions fair and careful consideration. His decisions, however, should be his own, and he should be certain and confident that they are right.

Natural ability is another fundamental qualification of the engineer. Every engineering educator with a conscience is forced often to debate with himself whether it would not be a real kindness to some well meaning but dull fellow to send him home. Nevertheless, we find occasionally that the comparatively mediocre student proves to have the most ability as an engineer after graduation, and we must always hesitate to pass judgments on young men which might ruin their chances for careers of highest usefulness. While only men with great natural ability achieve great success as engineers, yet there is room in the profession for many who can do useful work and earn honest livings in the rank and file.

33. **Technical Education Indispensable to the Engineer.** In the early days of engineering, and even up to a time within the memory of many prominent practitioners of the present day the necessity of an engineering education for an engineer was a disputed question. Much energy was wasted in discussions as to the relative merits of "theory" and "practice." The engineer who had received an engineering education was dubbed a "theoretical" man, while the man who had come up from the ranks without an engineering education was self designated a "practical" engineer.

All this is long since changed. It is universally admitted at the present day, since our calling has become a real profession, that engineering is so vitally based on science that a thorough engineering education is absolutely necessary to the engineer who attains the highest use of his natural qualifications. On the other hand, it is also generally admitted at the present time that an engineering education alone does not make an engineer. The engineering graduate is not yet an engineer. He has simply attained the possibility of becoming an engineer. In the engineering schools, as well as outside of them, the student is told over and over again that his engineering education merely puts him upon the threshold of the profession, and does not entitle him to membership in the fraternity. Practicing engineers and engineering educators are alike agreed on this point.

The engineering profession may be considered unanimous in supporting the idea that an engineering education is essential to an engineer of the present day. The common opinion has been well stated by Mr. Geo. S. Morison, who was one of the most prominent engineers of his day, in an address given in 1895, as

president of the American Society of Civil Engineers. In his address, he used the term "civil engineer" in the broad sense, as including all engineers not military.

"The civil engineer of the new epoch, the epoch which he is bringing into existence by the manufacture of power, must be an educated man,—in no profession will this be more necessary. The physical laws of power and strength are mathematically exact, and admit of no trifling. As the epoch progresses, the requirements for each individual will become more complicated. The theologian and the metaphysician may claim that an education based on the laws of matter leaves out the highest part of existence; the biologist and the physician may claim that matter endowed with life is a higher organism than the inanimate with which the engineer has to deal. But however true these claims, their laws have not the mathematical rigidity, the clear definition, and the thorough discipline which mark those with which our profession works. The engineer cannot shield himself under doctrines or theories which he accepts but cannot understand. Dealing with accurate, definite laws, and guided by the corrective touch of physical nature, the education of the engineer will become more necessary, more thorough, and more exact than that of any other professional man. This is the training which the civil engineer of the new epoch must have. This knowledge he must have, or he must be classed as a workman rather than the professional man."

In the education of the engineer, as in all his professional work, the *foundation* is of prime importance. The foundation of an engineering education consists of a thorough and broad study of all the fundamental sciences and general subjects upon which the profession is based. The purely technical part or an engineer's work consists in applications of the mechanical principles of forces and matter and hence it is especially essential that he should have made a very thorough study of physics and chemistry. In many lines of engineering, however, the engineer's work comes into the most intimate relation with other branches of science, such as bacteriology and botany. Hence a very thorough training in all the physical sciences is desirable.

The engineer's work is not restricted, however to technical applications of scientific law to inanimate matter. It is necessary for him to deal with men. Only through the agency of other men can he successfully direct the great sources of power in Nature for the use and benefit of man. Hence it is just as necessary that he should have a broad culture training as that he should have made a broad, thorough study of science. The technical knowledge of engineering will be of no benefit to him unless he can make actual use of it through the activities of other men, and that side of his work which includes the direction of bodies of men is really of higher nature than that which deals simply with inanimate matter.

It is necessary for the engineer to have thorough training in English and rhetoric, in order that he may express himself clearly and correctly. It is necessary for him to have some training in public speaking, in order that he may make a favorable impression upon boards of directors, municipal councils, and other bodies of men in reporting verbally upon his plans. It is necessary that he should be well informed upon history, and current events, in order that he may be qualified to associate with the leaders of communities. It is especially essential that he be well educated in the principles of political economy, in order that he may be qualified to direct great industrial enterprises, and to give service in connection with great public utilities.

The business side of an engineer's work is growing into very great importance, and is coming to receive special attention in engineering schools.

For all these reasons, therefore, the foundation of an engineering education is of prime importance. If an engineer had to choose between a good general education and one in narrow, technical lines, he would have better chance of success with the former, for it is possible for any well educated man to pick up in actual practice of the profession most of the technical details, but it is not practicable for one man in ten thousand to acquire a good general education anywhere except in an institution of higher learning. This fact is more and more plainly realized by engineering educators of the present day, and the tendency of engineering education is to lay the foundation broad and sure.

advance of his profession simply by reading current technical literature. In addition he should meet other members of the profession. He should present to them the results of his own experience, and in return receive the benefit of theirs. In order for him to do this it is necessary for him to have membership in both local and national engineering societies.

The local societies keep the engineers of one locality in close touch with each other, no matter what their special lines of work are, and enable them to assist each other in many ways, and to exert a powerful influence. The national societies, on the other hand, bind together all those engineers in the country who are engaged in any particular branch of the profession. The advantages of the local society therefore are more especially of a social nature, and in maintaining high local professional standards and correctly molding public opinion on local engineering problems.

The national societies secure organized action, in each great branch of engineering, of the engineers of the entire nation. They have power to establish standards for the profession which could not be imposed by other authority. They give it a standing which could not be otherwise secured. In addition they secure to their members the advantage and benefit of the experience and ideas of the very ablest men in their special branches.

Every engineer owes it both to the public and to the engineering profession at large, but more especially to himself, to obtain membership both in a local and a national engineering society.

37. **Broad Culture and Good Citizenship Necessary Qualifications of the Engineer.** In the discussion of engineering education considerable has already been said regarding the necessity for a broad cultural training of the engineer, but his education along these lines must not be considered to cease upon graduation from a college. The highest lines of engineering work are those which bring the engineer into leadership of large bodies of men. It is necessary, therefore, that he should keep in touch with the world's best ideas on commerce, economic questions, politics, literature and art.

If he should come into responsible charge of a great transportation company, for example, it is necessary that he should have the widest information possible concerning rate regulation, the effect of transportation rates upon the development of industrial centers, and the relations of capital and labor. If he has charge of a lighting plant or water supply company, it is necessary that he should be well posted upon all the relations of public utilities to the community. If he has responsible charge of a great manufacturing industry he must be well posted on business methods, the laws of supply and demand, systems of efficient administration, and the relations of capital and labor. In such enterprises the interests in the engineer's charge often have a close connection with political questions, and it is necessary that he should be well posted concerning politics. In all such enterprises, too, his success will depend in large measure upon his ability to influence both the men with whom he comes in immediate contact and the general public. He must therefore be a broad well rounded man, and a good citizen in every particular. He should read the best literature, study the best art, and he should conscientiously exercise his right of franchise, and keep well posted on all public questions. He should be a man of independent thought, and very conscientious in the exercise of his duties as a member of the community and a citizen of the nation.

38. **Definition of a Profession.** Statement has already been made that engineering is at once the oldest and the youngest profession, and that until 1850 it was not recognized as one of the learned professions. The query may properly be made: What is a profession? To this I might answer that the word itself suggests the answer. *A profession is a calling in society pursued by an organized body of men who profess to have certain knowledge, training and acquirements, fitting them to do work for society which cannot be done by ordinary individuals.* Those pursuing this calling *profess* to place themselves at the service of the public. They *profess* themselves to be bound by all rules of conduct and standards of action commonly appertaining to a profession. In

return for their services the members of a profession expect and demand from society rewards which would not be given to individuals not members of a profession.

39. **The Obligations of the Engineer as a Member of a Profession.** Engineers claim that theirs is a true learned profession, and one of the most important of the present day. It must be evident that engineers in becoming members of such a profession incur certain obligations to society, to their employers, to each other, and to themselves. Unless they fulfill the obligations of the profession, they must not expect its rewards.

What are the obligations incurred by the engineer of the present day as a member of his profession?

First, and most important of all, we may speak of his *duties to society in general*. A profession is simply an agency established by society, to do for it a certain line of work which the members of society in general are not qualified to perform. The engineer owes society, therefore, first of all, the faithful, honest and efficient performance of the duties of his profession.

He is also under obligation to become a good citizen in the community in which he lives, and, by performing these duties, to give society the benefit of his special technical knowledge on public questions.

He owes to society absolute honesty in all his life work. The engineer who is dishonest is infinitely worse than the ordinary thief, for the latter is under no professional obligations.

The engineer owes it to society not to undertake employment for clients whose plans in which the engineer is actively employed may tend to the injury of society. He should never lend himself to the promotion of unmeritorious inventions, for example, nor give endorsement, even by implication, to wild cat railways, or of mining properties whose values are not well determined and certain. It may be the duty of the engineer, at times to expose enterprises of the character mentioned above, even though he may have had no special concern in them.

Second, in his duties to his clients, the engineer should be bound by the same principles of ethics which are supposed to govern physicians and lawyers. He is bound, first of all to render efficient and honest engineering service. He should not undertake work for which he is not qualified. He should maintain secrecy as to his client's affairs just as is demanded of a physician or a lawyer. He should treat his client with courtesy and consideration, and demand similar treatment from him. He should be ready to explain in clear non-technical language so far as possible, the reason for his advice. He should strive to do the best for his employer's interests.

Third, in *his duties to the other members of his profession*, the engineer owes it to them to be a good, honorable, well qualified man. To maintain the standards of his profession, he must do nothing which could injure it in any way. A bad act on the part of the ordinary individual affects himself mainly; a bad act on the part of an engineer, on the other hand, injures the entire profession. This is true whether the bad act is due to dishonesty, immorality, or poor qualifications, but there must not even be a question as to the rectitude of an engineer.

The engineer further owes it to the other members of his profession to become a member of engineering societies, as already urged in Article 36; to prepare papers for their proceedings; to attend their meetings; and in general, to support them financially and as an active member. He also owes it to the profession to help support technical literature, by subscriptions, by reading, and by contributions thereto.

The engineer owes to the fellow members of his profession constant courtesy, and good will, and he should be bound by the same principles of ethics as are embodied in a fixed code by physicians, and which govern lawyers. He should not undertake any case upon which another engineer is employed, unless asked to do so by the engineer in charge, or unless the engineer formerly employed has been dismissed from the work. An engineer should not decry the work of his fellow practitioners. Every time he does so he lowers the public opinion of the profession.

The engineer owes it to his fellow practitioners to charge fees for his work at least equal to those customarily charged by other engineers for the same work. It is entirely unprofessional for an engineer to make a public bid for engineering service in competition with other engineers, and it is still more unprofessional for him to endeavor to secure any professional employment by underbidding other engineers or by decrying them to the authorities who have the selection of the engineer.

The engineer also owes it to the other members of his profession to assist in every way in his power to develop engineering education. His most active assistance in this particular should be afforded to his Alma Mater, as one of her alumni, by keeping in active touch with her engineering work, by offering advice from time to time, and by helping to keep up the spirit of loyalty among the alumni. For example, he should keep up correspondence and acquaintance with as large a group of alumni as possible. Further than this, any engineer should hold himself ready to respond to any reasonable call from any engineering school for information or advice or even for service to the extent of delivering non-resident lectures or addresses to the students.

Fourth, in *his duties to himself,* the engineer owes it to himself as well as to the profession, and to the world at large, to make the most of himself, as a man and as an engineer. His obligations to himself include the obligations to the public, to his clients, and to his fellow practitioners, which have been enumerated above. In addition he owes it to them as well as to himself to guard his self-interest, and to make the utmost of himself as an engineer.

40. **Codes of Engineering Ethics.** Owing to the fact that engineering has so recently been recognized as a profession, it has, as yet, no extensively recognized code of ethics. There has been much discussion on this subject, however, which has been very fully summarized by ex-President S. S. Wheeler of the American Society of Electrical Engineers, in his presidential address given at the 23d annual convention of the American Society of Electrical Engineers at Milwaukee, Wis., May 28, 1906, the subject of the address being "Engineering Honor." Mr. Wheeler quotes Francis Bacon, from his "Maxims of the Law:"

"I hold every man a debtor to his profession; from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereto."

In the appendix to his paper Mr. Wheeler presents abstracts of the codes of ethics of ministry, law and medicine, including a very full abstract of the principles of medical ethics of the American Medical Association, adopted in 1903. Mr. Wheeler also gives the code of ethics of the Boston Society of Architecture, which will be quoted in full herewith, owing to the similarity between architecture and engineering.

CODE OF ETHICS OF THE BOSTON SOCIETY OF ARCHITECTURE.

1. No member should enter into partnership in any form or degree with any builder, contractor, or manufacturer.
2. A member having any ownership in any building material, device or invention, proposed to be used on work for which he is architect, should inform his employer of the fact of such ownership.
3. No member should be a party to a building contract except as "owner."
4. No member should guarantee an estimate or contract by personal bond.
5. It is unprofessional to offer drawings or other service "on approval" and without adequate pecuniary compensation.
6. It is unprofessional to advertise in any other way than by a notice giving name, address, profession, and office hours, and special branch (if such) of practice.
7. It is unprofessional to make alterations of a building designed by another architect, within ten years of its completion, without ascertaining that the owner refuses to employ the original designer, or, in the event of the property having changed hands, without due notice to the said designer.
8. It is unprofessional to attempt to supplant an architect after definite steps have been taken toward his employment.

9. It is unprofessional for a member to criticise in the public prints the professional conduct or work of another architect, except over his own name or under the authority of a professional journal.

10. It is unprofessional to furnish designs in competition for private work or for public work, unless for proper compensation, and unless a competent professional adviser is employed to draw up the "conditions" and assist in the award.

11. No member should submit drawings except as an original contribution in any duly instituted competition, or attempt to secure any work for which such a competition remains undecided.

12. The American Institute of Architects' "schedule of charges" represents minimum rates for full faithful and competent service. It is the duty of every architect to charge higher rates whenever the demand for his services will justify the increase, rather than accept work which he cannot give proper personal attention to.

13. No member should compete in amount of commission, or offer to work for less than another, in order to secure work.

14. It is unprofessional to enter into competition with or to consult with an architect who has been dishonorably expelled from the Institute or Society.

15. The assumption of the title of "architect" should be held to mean that the bearer has the professional knowledge and natural ability needed for the proper invention, illustration, and supervision of all building operations which he may undertake.

16. A member should so conduct his practice as to forward the cause of professional education and render all possible help to juniors, draftsmen and students.

Mr. Wheeler also gives abstracts of many discussions on engineering ethics and related topics in engineering societies. While the adoption of a professional code has many times been proposed, yet it does not appear that any code has as yet been adopted, except in the case of the Canadian Society of Civil Engineers. According to Mr. Wheeler they have adopted the following code.

CODE OF ENGINEERING ETHICS OF THE CANADIAN SOCIETY OF CIVIL ENGINEERS.

Duty of the Engineer to his Client.

1. Every member of the society should perform the work he undertakes to do to the best of his ability, and in the true spirit of his engagement, feeling it to be his duty to present all ascertained facts in their true light.

The Client's Obligation to the Adviser.

2. The civil engineer has a right to expect from his client the same consideration and deference to his opinion, as is by their clients accorded to the members of other professions.—law and medicine for example—without which the adviser should decline to advise. The surest way for the engineer to obtain such necessary consideration and deference from the public will be found in this manner of carrying himself.

Mutual Relations of Chief and Assistant.

3. The assistant engineer must loyally obey and support his chief, to whom it will be his duty to report directly on all matters relating to the work on which they may be jointly engaged. His report should be full and explicit in all important points, and exact to the best of the assistant's knowledge and belief, cloaking nothing, even though going to show that previous reports had been inaccurate, or not duly weighed, in some particulars affecting the well-being of the business in hand.

4. The assistant engineer is entitled to look to his chief for, and to receive from him advice for his guidance on the proper performance of his duties, and where right to expect his support in matters of dispute between him (the assistant) and his subordinates or between him and the contractors working under him. He is also entitled to the aid of the chief engineer's professional experience or counsel where unlooked for or extraordinary difficulties present themselves, or changes of original plan may be called for, in work on which they are associated, so that responsibility may be fairly apportioned between them.

5. It is the duty of both chief and assistant, each in his department, to study economy in the doing of the work, the management of which they have undertaken, and in every way to make the client's interests the guiding object.

6. The engineer may legitimately suggest experiments with a view to improvement, whether in methods of doing the work which he oversees, or for raising its character, but such experiments should only be undertaken with the full consent of the party, whether client or contractor, on whom the expense may fall, and on the understanding that to them will accrue all pecuniary benefit from the success of the experiment.

7. It shall be considered unprofessional for any member of this society to seek the position of an expert to report on any work that is in charge of a recognized engineer.

8. It shall be the duty of any engineer, before examining any work with a view to report thereon, to give the engineer due notice before going on with the investigation, in order that he may have every facility to explain and sustain his methods of carrying on the work in question.

Professional Service of Engineers to Each Other.

9. Interchange of professional assistance between members, as tending to promote fraternal intercourse and mutual good will, is not to be discouraged, but neither is it to be considered obligatory on a member to respond to the request of a fellow member for professional counsel or assistance. Service so rendered must be entirely voluntary on the part of the member whose aid is sought.

Pecuniary Matters, Advertising, etc.

10. The Civil Engineer may consistently with professional status take out patents for new inventions or for improvements on old ones, and may sell or otherwise dispose of the patents for his own advantage. He may undertake the survey and the engineering of works by contract or he may contract for the construction of works on a percentage of their cost. Advertising with a view to attracting business should, where resorted to, be as far as possible free from egotistic or self laudatory references and expressed in language not derogatory to the dignity of the profession.

Duties of the Civil Engineer to the Public.

11. The civil engineer whose advice is sought in respect to the usefulness, practicability and cost of a work should, before expressing his opinion, obtain reliable information on all points involved in the matter submitted to his judgment, including the probably paying capacity of the contemplated undertaking. He must be cautious how he recommends large preliminary outlay, should avoid connecting himself with schemes or projects of merely speculative character, always bearing in mind that his professional reputation will be to a great extent judged by the inherent worth and commercial value of the undertaking with which his name may come to be associated.

Whether or not any fixed code should be adopted by the various branches of the engineering profession, it is certain that all engineers should be governed in their work by the full spirit of the codes which have been quoted.

41. **Engineers as Expert Witnesses.** Engineers are often called upon to serve as expert witnesses, and in such cases there are many puzzling questions of conduct which arise. In theory, the expert witness occupies a position different from all other witnesses. Other witnesses are allowed to testify only to *facts* which come under their direct observation. The expert witness, on the other hand, is allowed to testify as to his *opinions* on questions which are presented to him.

He occupies, then, something of the position of the judge himself. If it were possible to have the ideal conditions, all expert witnesses should be appointed by the court, and paid the same as the judge and other members of the court, instead of by either party to the litigation. In fact, however, it is impossible to have this ideal condition of affairs, without abridging the right of each party to the litigation to present all facts favorable to his own side of the case.

The expert witness, therefore, must appear under the circumstance of being employed and paid by one of the parties to the litigation, while at the same time he is under obligation to the court and to the public as a whole to be fair and un-

biased. He should never appear as the mere paid employe of the litigant, but should fulfill to the utmost the obligation of his oath to tell "the truth, the whole truth and nothing but the truth."

In common custom, there is a preliminary conference between the expert witness and the litigant who desire to have his services. In this preliminary conference the engineer should obtain full information as to all the facts, should inform his prospective client fully as to his honest opinions, and he should not undertake service as an expert witness unless he has an honest conviction of the justice of his client's case. When on the witness stand the expert witness should not attempt to suppress any part of the truth, even though such suppression should be to the advantage of the litigant who has employed him. Although, in all conferences, it will be his duty to inform his client fully on all technical matters which might favor his side of the litigation, yet the expert witness should adopt a perfectly fair and non-partisan attitude.

42. **The Mission of the Engineer.** The substance of the discussions in this chapter is that the mission of the engineer is service to modern society.

It is his place to direct for the use and convenience of man the mechanical forces and powers of nature. It is by progress along engineering lines that the world has risen from savagery to its present high advancement in civilization. Without the engineer, the world today would not find it possible to occupy its present advanced standing in any line of human activity. In the hands of the engineer are placed, in large degree, not only the life and material welfare of his fellow men, but also the conquest of the forces of the universe for intellectual and moral advancement. He should keep this high mission fully in mind.

To quote from a verse by Maltie D. Babcock, carried for years in the pocket of a prominent engineer,—

"Be strong: We are not here to play, to dream, to drift,
We have hard work to do, and loads to lift:
Shun not the struggle, face it, 'Tis God's gift."

PART II.

ENGINEERING IN THE SAVAGE CULTURE STAGE.

CHAPTER IV. HISTORY OF THE SAVAGE CULTURE STAGE.

43. **The Antiquity of Mankind.** (Note: The student should now carefully re-read Article 6, page 10.)

There is no history of the savage culture stage, in the sense of written history, based on contemporaneous written record. What we know of savage history, except as savages appear in the histories of other peoples of higher culture stages, is ascertained by inference, from scientific study: *First*, a direct study of existing savage tribes, which can still be found in many and widely varying stages of culture, development; *second*, a study of the remains of pre-historic man and his work.

It is by this second line of study, combined with the study of Geology, that estimates have been made of the antiquity of the human race. Authorities differ enormously in the periods assigned. The estimate of 200,000 years, mentioned in Article 6, page 10, is stated by Hittell* to be based on the opinions of Ceike, Croll, Lyell, and other good authorities.

The rocks of the earth's crust are classified as unstratified, or fire fused, and stratified, or water laid. Only the latter show traces of animal or vegetable life of any kind. Geology divides the stratified rocks, beginning with the oldest, into the following epochs (as given by James Clodd, in "The Story of Primitive Man," Chapter 2, page 20).

	Estimated depth.		Typical Plants.	Typical Animals.
Primary	136,000 ft.	72 %	Seaweeds and ferns	Fishes
Secondary	25,000 ft.	13.4 %	Pines	Reptiles
Tertiary	27,000 ft.	14.6 %	Leaf-bearing trees	Mammals
Quarternary and recent	500 ft.		Existing species	

*(Mankind in Ancient Times.) Vol. I, page 18.

The Tertiary period is further sub-divided into three periods; namely, beginning with the oldest, the Eocene, the Miocene and the Pliocene. Probably the earliest remains of man yet discovered consist of very rudely worked flints, found at Thenay in France, and near the Tagus in Portugal, all in Miocene beds. The human origin of these flints is yet disputed. If proven, it would indicate, of course, that human life originated much earlier still, and would show a much greater antiquity for mankind than 200,000 years. There are other reasons besides the discovery of these flints for inferring that mankind first appeared at about the close of the Eocene, or the beginning of the Miocene period.

At the close of the Tertiary and the beginning of the Quarternary epochs occurred the great Glacial Periods of the northern hemisphere, during which there were several successive advances and retreats of the great ice sheets. The Pleistocene geological period extends from the beginning of the glacial period down to the present period. It seems assured, from many finds of worked flints, that mankind existed during the glacial period, though there was at first considerable dispute over this subject. The first finds of worked flints in glacial (drift) deposits occurred near Abbeyville, France, in 1839. Numerous similar finds have since been made in other portions of the world, but their authenticity is not so generally accepted.

Illustrative Lantern Slides. No. 53. Flakes from Pliocene Beds, Yenangyoung, Burmah, India, from *Natural Science*, November, 1894. Showing rude character of most ancient alleged "Worked Flints."

44. **Outline of History of the Savage Culture Stage.** The savage culture stage has extended from the origin of human life down to a comparatively very recent time. For a considerable fraction of the human race it has extended down even to the present time, for there are still hundreds of millions of living savages (see Article 6, page 10). This long period may be divided into the following culture stages:

1. *The Pre-Fire Stage.* Of this there are no known remains.
2. *The Paleolithic Stage.* or *The Stage of Rude Savage Culture*, characterized by *Rude Stone Implements.* This occupies by far the greater portion of the Savage Culture stage, and is still represented by many living savage tribes.
3. *The Neolithic Stage* or *the Stage of Advanced Savage Culture.* characterized by *Skillfully Made Stone Implements.* This age represents the highest savage culture and did not begin till a comparatively very late date. It is still represented by numerous living savage tribes.

45. **The Pre-Fire Age.** Since no animals, not even those of the highest type, make use of fire, it must clearly be apparent that there was a period, immediately following the origin of human life, when mankind did not have the use of fire. Of this extremely early period, we have, however, no direct evidence. It has no living representative among the savage tribes of the present day, although* some Australians and Tasmanians do not know how to kindle fire, and hence must constantly carry it with them.

46. **The Paleolithic Culture Stage.** The Paleolithic culture stage has extended, as has already been indicated, over by far the greater portion of the life of mankind. It is perfectly conceivable that the rude shaping of flints may have begun in the Pre-Fire age, although the earliest flints yet found show traces of splintering by fire.** As some savage tribes of the present day are still in this stage, there is no exaggeration in saying that the Paleolithic culture stage has continued nearly as long as human life itself.

During the Paleolithic culture stage there was a gradual, though very slow progress towards civilization, as is evidenced by the improvement in skill in

*Hittell Mankind in Ancient Times. Vol. 1, page 51.

**The disbelievers in the human origin of these flints attribute the traces of fire to the effects of lightning.

the manufacture of chipped stone implements and other implements and ornaments shown in the specimens which have been found in successive layers of remains. However, of later years archaeologists have come to realize that many rude chipped flints formerly supposed to be Paleolithic are simply partly made stone implements, rejected and never completed because of flaws or other defects. It is estimated that at least ten stone implements were started for one finished. These "rejects" are found in greatest abundance near the spots where suitable stone was quarried or found. It used to be thought that the stage of chipped stone implements invariably preceded that of ground or polished stone implements, and the term Paleolithic stage was synonymous with that of chipped stone implements, while Neolithic was synonymous with the stage of ground and polished stone implements. It is now realized that the method of manufacture depended largely upon the material, and that in some regions chipping may never have prevailed at all. Hence the best practice now is to define the terms Paleolithic and Neolithic as applying, respectively, simply to the rude and the advanced stages of savage culture.

Illustrative Lantern Slides. No. 48. Ealing Dean (England). No. 70. Hackney Downs Gravel (England). Both from *Ancient Stone Implements*, by Sir John Evans, showing character of the rude chipped stone implements from the glacial drift gravels in Europe.

The Aleut Mounds. Along the shores of the Aleutian Islands, between North America and Asia, a large number of ancient village mounds have been found and examined, which show in successive layers the progress, through a very long period of time, of savage peoples, from the rudest stage of culture, without positive evidence of knowledge of fire, to a much more advanced Paleolithic age. In the lowest stratum only shell fish, apparently, were used for food, and the only artificially shaped implements found were rude hammers, stones with slight hollows on opposite sides for the fingers. The lowest stratum of these mounds represents perhaps the lowest savage culture yet found.

The Drift Men. The earliest stone implements, very rude in character, have been found imbedded in gravels of the Glacial Period. Well authenticated finds have been made in Europe and others have been claimed in Asia, Africa, and America. In the Somme River Valley, in France, these remains are of such ancient date that the river has had time, since they were deposited, to scoop out its valley 60 to 100 feet, an operation which certainly required an enormously long period.

The Ancient Cave Men. Of a considerably more advanced stage of savage culture were the "cave men," of whom numerous traces have been found all over the world in caverns, such as frequently occur in limestone strata. The European caves have naturally been studied the most thoroughly. They were occupied through long periods of time, and the human remains are found in successive layers, of which the oldest are often buried under stalagmitic stone floors, which have in some instances attained a thickness of several feet. The European cave men* had axes and chisels of flint, bows, arrows, arrow straighteners, barbed fishing and fowling spears, daggers, marrow spoons, needles, skin scrapers, amulets, etc. Numerous traces of fire occur among the remains. The cave men of all except the topmost stratum of remains did not have polished stone implements, nor pottery, nor any regular use of metal.

47. **The Neolithic Culture Stage.** The Neolithic culture stage began, of course, at different dates in different countries, and in some parts of the world, in fact, has not begun even yet.

According to Isaac Taylor,** estimates of the time elapsed since the beginning of the Neolithic age in Europe vary from 2000 to 6000 years. Since Egypt and Chaldaea advanced to the culture stage of Barbarism several thousands of years before Europe, a still earlier date might reasonably be assigned

*Hittell– Mankind in Ancient Times. Vol. 1. page 45.
**The origin of the Aryans, pages 58-63.

for the beginning of Neolithic culture in those regions. However no very sharp lines of demarcation can be drawn between Paleolithic and Neolithic culture, and no well established date can be assigned for the beginning of the Neolithic stage.

While the Neolithic stone age is distinguished especially by that advanced stage in the manufacture of stone implements in which the work was done by grinding and polishing rather than chipping, yet it should clearly be understood that this was only one of many advances in culture. Among the other advances may be mentioned, pottery, the manufacture of cloth, and canoes, the use of domesticated animals(beginning with the dog), tillage of the soil, fixed government by chiefs, definite religious beliefs, and advances in social organization generally. The use of chipped stone implements, for many purposes, continued during the polished stone age.

The Danish Mounds. It is stated by good authority* that probably the earliest traces of men who used polished stone implements are found in the peat bogs and village mounds of Denmark. These and other village mounds are often referred to as "kitchen middens." Some of these mounds are 900 feet long by 180 feet wide and 8 feet high, composed of a mixture of shells, bones, ashes, charcoal and earth. There is evidence of their great antiquity in the fact that the lowest strata show remains of trees and shell fish long since extinct in that part of Europe.

48. **Lake Villages.** Worthy of a separate article, though coming in the main under the Neolithic culture, are the lake villages of some modern savages and the Swiss Lake Villages of Pre-Historic Europe. These villages were built out in the lakes, on platforms supported by piles, in order to afford greater security from enemies.

The Swiss Lake Villages belong to the latest stage of Neolithic culture and in many instances endured into the age of Bronze. Hittell states that 133 sites of such villages, in 16 Swiss lakes, are known, and that the study of the remains of these villages has afforded the largest body of information existing about pre-historic savages.

The piles were sharpened at the bottom by stone axes, and by fire, and were morticed at the top to support the platforms on which the houses were built. The inhabitants must have had an advanced communal organization. They cultivated wheat, barley, millet and caraway. They gathered wild fruits, berries, and nuts—including apples, pears, cherries, grapes, strawberries, blackberries, beech nuts, and walnuts. They had many domestic animals. Pottery was abundant. Pieces of yarn, thread, rope, woven cloth and matting have been found among the remains. There were many implements of stone, bone, horn and wood. They had rude dugout boats.

Illustrative Lantern Slides. No. 11. Reconstructed Swiss Lake Village, from *Primitive Man*, by Hoerness, frontispiece. No. 75. View of modern Lake village, town of Brunei, from *Story of Primitive Man*, James, Clodd, page 133. Credited to Clutterbuck.

49. **The Mound Builders.** The Mound Builders of the Mississippi River Valley are another Neolithic Savage culture people worthy of a separate article. Their work has been very extensive and covers a wide region. The total number of their mounds has been estimated* at 50,000. There are 13,000 in Ohio, and 5,000 in Illinois, within a semi-circle of 50 miles radius, with the mouth of the Illinois river as center. The mounds are 5 to 90 feet high, and one of the largest, at Cahokia, Illinois, is 700 feet by 500 feet high, containing 740,000 cubic yards. In Fort Ancient, Ohio, the works are nearly a mile long, with more than 20,000 feet of wall and more than 5 miles of terraces.

The mounds are of various shapes, some imitating animals. They are supposed to have been constructed for defense, and in some instances, for public worship. In numerous instances the mound builders erected low stone

*Mankind in Ancient Times, Vol. 1, page 47.
**Hittell's Mankind in Ancient Times. Vol. 1, page 39.

walls, not connected with mounds. Of the origin of the mound builders, their antiquity, and the nature of their culture we have no direct historical evidence. A study of their implements and other remains, however, shows them to have been in the Neolithic culture stage. In the mounds there have been found many stone implements, vessels of unglazed pottery, net sinkers of galena lead ore, implements and ornaments of bone and shell, etc.

Of special interest are ornaments and knives of beaten copper, and simple ornaments of silver. The copper undoubtedly came from the Lake Superior copper region, where many rude pre-historic mines have been found. The fact that it was not cast, and that no bronze articles have been found shows that the mound builders had not risen to the barbaric culture stage. It is now well agreed that the mound builders were simply the predecessors, and probably the ancestors, of the American Indians of the same region. It is surmised that the population may have been denser when the mounds were built than later.

Illustrative Lantern Slides. No. 101. The great mound near Miamsburg, Ohio. No. 102. An aboriginal copper mine in the Lake Superior copper region. No. 103. Beaten copper knives and tweezers, from the mounds. No. 104. Pottery from the mounds. All from Baldwin's *Ancient America.*

50. **The Pueblo Indians.** Of a still higher stage of Neolithic Savage culture are the Pueblo Indians of the Southwestern United States. These Indians built communal houses of Adobe and other masonry, constructed irrigation work on quite a large scale, and showed much skill in the manufacture of pottery and cloth. In many of the pre-historic instances their dwellings were constructed, for purposes of defense, in inaccessible positions on the faces of cliffs and the sides of canyons, as is evidenced by numerous remains of such dwellings which still exist. These pre-historic tribes are denominated the *Cliff Dwellers.* A few tribes of Pueblo Indians are still in existence in the southwestern part of the United States, and a study of them has afforded a large amount of most useful information on advanced savage culture. The Zuni and Hopi tribes are well-known examples. In the past the Pueblo population must have been much more extensive than at present. The Pueblo Indians have attained a very high stage of savage culture, as is proven by their communal masonry houses, their skilled manufacture of pottery and cloth, their expert tillage of the soil, and their construction of irrigation works on a large scale. (See article 74.)

Illustrative Lantern Slides. No. 105. Pueblo Ruins, from Baldwin's *Ancient America.* No. 106. Cave dwelling with Aboriginal stairway. No. 107. Cave dwelling with Graded way. Both from Mason's *Origins of Invention.*

CHAPTER V.

SAVAGE IMPLEMENTS AND MATERIALS OF CONSTRUCTION.

51. **The Conquest of Fire.** It has already been stated (See Article 45) that no living savages have been found so low in culture as to be without the use of fire, but that there must have been a pre-fire age.

It is surmised that the conquest of the use of fire came about through repeated experience, through many ages, with fire of natural origin. Lightning sets many a dead forest tree ablaze, and volcanoes in some regions constitute another natural source of fire. Earthquakes have been known to start fires by percussion or friction of rocks. Even after they had mastered its uses, savages at first had no means for artificially kindling fire, and they carried it with them, carefully guarded, from one place to another, just as do some Australians and Tasmanians of historic times.

Gradually, however, artificial means for kindling fire were invented and developed. The savage devices for this purpose fall naturally into three classes, as follows: 1. Those developing fire by friction; 2. Those developing fire by percussion; 3. Those developing fire by compression.

1. *Friction Devices for Kindling Fire.* Of these the simplest, and probably the first developed, was that of simply *rubbing together two pieces of wood,* until the heat developed set fire to very inflammable material (tinder). This operation is one which is so difficult as to require much skill in selecting the material and carrying on the process. Usually a hard stick is rubbed in a grove in soft wood until fire is set to wood dust shavings or tinder. When the groove is parallel with the grain the process is called *ploughing;* when across the grain, *sawing.*

The Fire Drill is a pointed stick of hard wood, rotated rapidly while being pressed into a hole in soft wood. The rotation may be: (a) simply between the palms of the hands; (b) by a cord pulled back and forth by two hands; (c) by a loose bow string worked by one hand; (d) by up and down motion of a hand piece, through twisted cords and a spindle wheel. With any of these forms of drill a top horizontal cross piece is generally used to permit pressure to be applied conveniently.

In all these cases of making fire by friction a wood dust is produced, and heated till it ignites. By fanning, a blaze is started, and fed with tinder and dry grass. The knack must be acquired by repeated experience.

2. *Percussion Devices for Kindling Fire.* In these a spark is usually struck from flint into tinder until it is kindled. The striking piece may be: (a) a piece of hard wood, such as bamboo; (b) a piece of tough stone, such as iron ore; (c) a piece of metal, but this would not ordinarily be used in the savage culture stage.

3. *Compression Devices for Kindling Fire.* In the Smithsonian Institute —Report for 1907—a paper will be found* which gives a full description and discussion of the *Fire Piston.* It consists of a hollow wooden cylinder, and a piston fitting therein. By sudden compression of the air in the cylinder by the piston, heat is developed sufficient to kindle wood dust or tinder. This device was re-invented in modern Europe prior to the introduction of matches.

Illustrative Lantern Slides. No. 7. The simplest fire drill (after Hough), rotated between palms. No. 1. Two handed fire drill, Kuskokwin region, Alaska, rotated by cord pulled back and forth, with cap piece and wooden hearth. Both above from *Origins of Invention,* by Mason.

52. **Material of Construction in the Savage Culture Stage.** Under the term "Materials of Construction" there will be included materials used for implements and ornaments of all sorts.

While stone is so characteristic a material of savage construction that it has given the name "The Stone Age" to savage culture, yet it is by no means the only material used by savages, nor was it even, probably, the first material used.

The materials of savage construction may be enumerated as wood, horn, ivory, shell, stone, earth, vegetable and animal fibres.

The uses of wood, stone and earth are worthy of separate articles.

Bone, horn, ivory and shell were extensively used from the earliest stages of savagery, as materials for the manufacture of all sorts of implements. In fact, they were undoubtedly originally used in unchanged, natural shape, as rude implements. Horn is used by Esquimos of the present day, even in the construction of bows, and they make beautiful implements and parts of implements from walrus ivory. The first shovel may have been the shoulder blade of some animal, the first knife a sharp shell, the first dish the covering of some large shell fish.

53. **Uses of Wood by Savages.** The uses of wood were manifold. Probably the first tool invented by man was a club of wood, and such tools are used even by the higher animals. In the savage culture stages wood was used for the manufacture of innumerable implements and weapons; including clubs, bows, arrows, handles of other implements, swords, bowls, digging

*The Fire Piston, by H. A. Balfour.

sticks, spades, etc. It was also used for the construction of dwellings, boats and even bridges.

54. **Earth as a Material of Savage Construction.** Earth was used for many purposes in savage construction. It was first heaped into mounds, on which the rude dwellings were elevated above the surrounding surface, for health and for defense. Later on it came to be piled in mounds of great size, such as those already described in article 49, which marked the highest attainment of savage construction along this line. Clay, mixed with water, and kneaded constituted the first mortar, and, in general, savages do not seem to have progressed beyond this sort of mortar in their masonry construction. Adobe was devised and used extensively by many savage peoples. It consisted of clay mixed with water, kneaded and shaped into blocks, walls, etc., from which extensive buildings were constructed in climates with small rainfall, such as those of south-western United States. In other climates, clays or other ingredients with special properties may have been used.

Earth in the form of clay was also used in the construction of pottery, one of the first savage industries to receive development.

55. **Uses of Stone as a Material of Savage Construction.** It has already been stated that stone was such a characteristic material for savage construction that it has given the name "The Stone Age" to the savage culture stage.

Not all sorts of stone, however, were valuable for use in implement making. By infinite numbers of trials with different kinds of stone, savages learned the best materials available in each region.

They resorted to the places where these materials could be found most plentifuly. Where the materials occurred in solid layers regular quarries were worked; and where, as is often the case, the source of the material was the boulders and pebbles of gravel strata, such strata were turned over and over to meet the needs of successive generations. Modern scientists have discovered many sites of pre-historic quarries and workshops for stone implements.

Besides being used for the manufacture of implements, stone came to be used, in a later portion of the savage culture stage, in the construction of dwellings, fortifications and monuments. As already stated, the mortar was earth mixed with water and kneaded, and in many cases also mixed with sand and pebbles.

56. **Manufacture of Chipped Stone Implements.** Wherever suitable materials were available, the first method of manufacturing stone Implements devised was that by chipping. Early man found by experience that stones with sharp edges were useful as rude implements. The idea would next occur that the sharp edges could be artificially produced by breaking off one side of one stone by blows from another. Repeated trials would eventually develop the method of manufacturing chipped stone implements.

The first thing neccessary in connection with the manufacturing of a chipped stone implement was to find a piece of satisfactory material. It may be supposed that savages were constantly on the lookout for good material for stone implements, and it has already been stated that they resorted in great numbers for generations after generations to particular places where such materials were found. Flint, chert, quartzite boulders, quartz pebbles, rhyolite quarried from the mass, jasper quarried from the mass, and obsidian are some of the principal materials suitable for this purpose.

In the case of some of the most favorable materials, such as large blocks of obsidian, and masses of flint, it was possible for the workman at a single blow to strike off a piece of material a foot long, which would serve as a very useful knife.

Most of the implements, however, were constructed by a laborious process. On first finding the material, the implement maker would roughly shape it, usually on the spot. In many cases the stone would be thrown away on account of flaws developed after one or two blows. Such discarded pieces

after one side had been shaped. It has already been stated that many erare called "rejects." In other cases the "rejects" would be thrown away roneous conclusions were formerly drawn as to the culture stage to which certain stone implements belonged, because the existence of a great number of "rejects" was not recognized until recent times.

Illustrative Lantern Slides. No. 81. View of aboriginal quartzite quarry in Wyoming, showing one of the pits in the quarry dug out by Indians to obtain the material for stone implements. Good materials found in small masses scattered through the other layers. (From George A. Dorsey). No. 36. View showing the elaboration of chipped stone implements, with "rejects"on the left, more advanced forms in the middle, and finished forms on the right. The upper line shows implements from quartzite boulders, the second line from quartz pebbles, the third from rhyolite quarried, in the mass, and the last line from jasper quarried in the mass. (From W. H. Holmes). No. 18. Flint knife, showing how a cutting blade of flint can be chipped off from a flint core to make a useful savage implement. (From "Primitive Man", by Hoerness).

In the process of finishing up the chipped stone implements, more delicate chipping and flaking were necessary. This was performed by very light blows repeated many times, requiring great skill on the part of the workman. No one at the present day can form such perfect stone implements as are known to have been the regular product of many savage craftsmen.

Besides the method of flaking by striking blows, the use of pressure was common in the manufacture of chipped stone implements. Among many savage tribes, special tools for this purpose were found. A common Esquimo chipping tool consists of two parts: First, a handle of walrus ivory, curved and fitted with utmost care, and highly polished, exactly fitting the chipper's palm, and enabling him or her to have the firmest grasp, and exert the utmost pressure; second, at the working end of this handle, a strip of very hard antler or bone, let into a groove, about two inches long, by one-half inch deep, by a quarter of an inch in width extends, say, one inch beyond the end of the handle, so as to come into contact with the stone to be chipped.* By rapidly repeated strokes with this instrument, small flakes of stone are broken off in the final shaping of the implement.

Mason, in his "Origins of Invention," gives the following classification of aboriginal stone workers, or stone workings:

1. The stone-knapper, makers of spalls, and artefracts with large facets. Their implements were at first other stones, then stone hammers, specially selected and formed, and after that knapping hammers of metal. The art consists in breaking stone with a blow.

"2. Stone chippers and flakers, makers of chipped products. Their tools were small hammers of stone, but more especially pointed pieces of bone or antler, which were used as pitching tools, or for pressure.

"3. Hammers of stone. Makers of mortars, pestles, axes; sculptors of all kinds. Their apparatus was the stone hammer, ancestor of modern bush-hammers.

"4. Stonecutters, *par excellence*. Workers in soft materials at first, such as soapstone and the less compact volcanic rocks. The tools were chisel-like, or gravers, and were worked with the hands rather than struck with mallets. The modern carvers are their descendents.

"5. Sawers of stone and other hard metals. Their tools are not well understood, since, strange to say, very few white men have ever reported observations on the subject.

"6. Borers of stone. Their tools were drills, of soft material, chiefly used with sand, and in boring soft stone, harder stone points.

"7. Polishers of stone. Other stones, with or without sand, and corals or achres, were the means employed. It was well known to the early artifi-

*Mason's. "The Origins of Invention." Page 134.

cers of this class that the dust of any stone was its best polisher. After the same fashion, the diamond is polished with diamond dust,"

Mason also states that a complete catalogue of aboriginal workmen in stone would have to include also the quarriers of stone, working "with rude shovels of scapula, crow-bars of hard wood, burnt at the end, sledge hammers of huge boulders, with or without hafting, and a skillful use of fire and water."

Illustrative Lantern Slides. No. 35, showing method of removing flakes by blows with a piece of stone. No. 6, showing method of removing flakes by pressure with a chipping tool. Both of the above from Origins of Invention, by Mason. No. 66, showing a flint core with the flakes which have been removed replaced upon it. No. 67, showing arrow heads illustrating the most expert work in stone chipping. Both of the above from Evans' Ancient Stone Implements.

57. **Manufacture of Stone Implements by Hammering and Pecking.** Another method of manufacturing stone implements is indicated in the quotation above, from Mason, as being hammering. Many examples have been found of ancient stone hammers used in this work. A series of light strokes was struck with the hammer upon the stone to be battered. Mason states that savages would select the toughest bit of stone accessible for a hammer, and then holding this in the right hand between the thumb and middle finger, with the forefinger at the top would strike about a hundred blows per minute, brushing away the loosened material from time to time with a broom of stiff fibres. In many of the ancient hammers hollows have been worked on opposite sides for inserting the thumb and fingers. In other working in stone the hammers were hafted.

Illustrative Lantern Slides. No. 82, showing pectolite hammer with handle of caribou antler, grooved to fit the hand. This hammer would be adapted to heavier work than that described above. From Mason's Origins of Invention, page 52.

The process of manufacturing stone implements by hammering, or pecking, should be considered not necessarily as succeeding the method of chipping, in point of time, but as the original rudest method in many cases.

58. **Manufacture of Ground and Polished Stone Implements.** The methods of manufacturing stone implements described in articles 56 and 57 by chipping and pecking were used in a very crude manner and afforded only very rude implements at first. A higher skill was developed only by very slow improvement over a period of tens of thousands of years.

As we come to the Neolithic Culture Stage, we reach the highest development of skill in the use of both of these methods, and in many cases stone implements came to be ground and polished. The ground and polished implements are characteristic of the Neolithic Culture manufacture of stone implements. Besides grinding and polishing, the savage craftsman came to saw, drill, and otherwise shape stone, into many kinds of implements and weapons.

Illustrative Lantern Slides. No. 57, showing ground and polished ax-heads, in one case with cavity on sides for finger holds. No. 52, showing perforated ax-heads and hammer stone.. No. 62, showing a perforated ax, and one mounted in a staghorn socket. All three of these slides illustrate the most advanced stage of the savage stone workers art. All are from the Story of Primitive Man, by Edward Clodd.

59. **The First Metals.** In the latter part of the Neolithic culture stage, and even earlier in the case of tribes located in particularly favorable regions, savages usually became familiar with a few of the metals which occur in the free state, including, especially copper, gold and silver. Undoubtedly copper and gold were the first metals known to man. Both appear in the free state, and gold is distributed in greater or less quantity over a large portion of the world, while copper, in certain regions, is much more in evidence in the free state than gold.

There has long been much dispute as to which metal was probably first known to man. The preponderance of opinion seems to be in favor of copper.

The central portion of the United States, from the Lake Superior region to the southern limits of glacial action, at about the latitude of St. Louis, was especially favored as regards the distribution of free copper. Pieces of the metal are still turned up by the ploughman in many a furrow, or exposed in the digging of many a post-hole. The writer of these lectures has seen a mass of pure copper as large as the head of a man which has been found at the surface of the drift soil in Northern Illinois. It is not an infrequent experience at an institution of learning in the Upper Mississippi Valley regions to have samples of pure copper submitted by the finder, who thinks he has discovered a mine of the metal.

In article 49, the statement has already been made that the use of copper was known among the Mound Builders of pre-historic America, and in the illustrative lantern slides a view was shown of an aboriginal copper mine in the Lake Superior region, and of copper implements, beautifully finished, taken from the mounds of the Mississippi Valley.

However, copper in the pure state is too soft to make satisfactory cutting tools, and stone, for many purposes, furnished better implements for savage uses. Hence copper did not displace stone implements among savage tribes until they had discovered how to harden it by the admixture of tin, thus producing bronze. The discovery of bronze marked the transition to the barbaric culture stage. Savage artisans were unable to cast even the pure copper, on account of their inability to make fires hot enough to melt it, and it is supposed that all savage copper implements were made by hammering and grinding the cold metal.

Silver was the rarest of the three metals which have been named as those first known to man.

Certain modern savages are acquainted with the use of iron; as, notably, in Africa, where they smelt it by crude methods from the ore, and manufacture it into many varieties of weapons and other implements. It is presumed, however, that their knowledge of this metal has been acquired from people of higher culture stages, and thus is not a purely natural development. In the purely natural development of culture the use of iron is characteristic of the latter part of the barbaric and the beginning of the civilized culture stage.

Illustrative Lantern Slide. No. 22, showing copper ax from Swiss Lake Village (From Primitive Man, by Hoerness). By comparing the form of this ax with those made of stone, as illustrated in article 58, it will be seen that the form of stone implements was imitated in the first implements of metal.

60. **The Mounting of Stone Implements.** In the case of prehistoric stone implements, which have been discovered in such great numbers by antiquarians, the handles and other mountings have usually disappeared, for the reason that they were made of wood or other perishable material. We must suppose, however, that all but a small number of these ancient stone implements were mounted in handles or other attachments for convenience and efficiency of use, and this idea is confirmed by study of the practice of modern savages.

In the rudest stage of culture the practice would be to simply take the stone in the hand. The inconvenience and discomfort of so using the implement would finally lead to the next step, which would be to provide a covering, or grip, by which the holder would more readily, and comfortably grasp and use the implement.

Illustrative Lantern Slides. No. 3, showing the dagger of a California Indian, the hand grip being simply a long strip of otter skin, bound around. No. 27, showing the "The Woman's Knife." the grip being simply a lashing of fibres to protect the hand and enable a firmer grip. (Both the above from Mason's The Origins of Invention).

The next step would be to provide a handle, which in addition to affording a convenient method of grasping and using the implement, would give greater force and efficiency in its use. Many methods of attaching the handles were devised among savage people.

Mason enumerates the following principal types:

"1. Doubling a pliant loop of wood about the working part.

"2. Fastening the working part to a shoulder on the handle, or to a forked stick.

"3. Inserting the working part into a hole, or groove, or mortise in the handle.

"4. Inserting the handle into or through the working part.

"5. Binding the working part in a sling, which either encircles or covers it.

"6. Seizing.

"7. Gluing.

"8. Rivetting."

Illustrative Lantern Slides. No. 77, showing Australian flint knives, (the handles consist simply of wrappings and lashings) and also an Indian stone ax, from the Rio Frio, Texas, mounted on a wooden handle. (From the Story of Primitive Man, by Edward Clodd). No. 39, showing Hupa dagger, Northern California, the handle mounted in pitch. No. 44, showing a similar primitive knife from California, the head being held in place by lashing and pitch. (Both the above from the Origins of Invention, by Mason). No. 19, showing flint blade, and also stone ax, with nephrite blade mounted in staghorn and then fixed in wooden handle. (From Primitive Man, by Hoerness.) No. 69, showing polished celt, or ax-head, mounted in perforated wooden handle. (From Evans Ancient Stone Implements).

61. **Savage Weapons.** Undoubtedly, the human race, like the animal race in general, has always been engaged in a constant struggle with other species for mere existence; hence, weapons have always been a prime requisite for existence and progress.

A classification of savage weapons, modified from the one quoted by Mason on page 372 of the Origins of Invention, would be as follows:

1. *Bruising Weapons.* In the hand: The fist, with or without a stone or mass of other heavy material.

With a handle: Clubs, flails, scourges.

Projectile: Stones, throwing clubs, blunt arrows, stone bullets, (as from a sling).

2. *Piercing Weapons.* In the hand: Daggers and pointed knives.

With a handle: The spear and the pick.

Projectile: Arrows from a bow, darts from a blow gun, or thrown with a throwing stick, javelins, harpoons and spears, thrown from the hand, with a cord, or with a throwing stick, or spear thrower.

3. *Cutting Weapons.* In the hand: Knives, swords with stone blades.

With a handle: Hatchets, axes, including battle axes.

Projectile: Bladed arrows, African throwing knives, boomerangs.

Undoubtedly, the first weapon employed by savages was the club, which has been extensively elaborated among savage people. In many cases much work is bestowed upon its shape and ornamentation.

Much savage ingenuity has been shown in devising various kinds of weapons, both those for the hand and missile weapons. The bow is one of the great inventions of the human race, and continued the principal projectile weapon throughout the savage and the barbaric culture stages, and even in the civilized culture stage down to within 500 years of the present day. The crossbow was generally unknown to savages, although it has been used by them to some extent. In a few instances bows have been devised for throwing stone bullets, but in general, these have been reserved for the sling. However, the sling has never had so extensive a use as the bow.

Much ingenuity has been shown in the invention of throwing devices for spears, javelins, harpoons, etc. Many savage tribes have learned that greater accuracy is secured by rotation, and suitable devices have been used to insure rotation of the projectile.

The boomerang is one of the most ingenious of savage projectile weapons thrown from the hand.

The blow-tube may be considered a high development of savage weapons. Small darts are thrown from it, whose points are poisoned. The tubes are constructed from hollow reeds or canes, and in some cases by making artificial grooves in two semi-circular pieces of wood which are then lashed together. The propelling power is compressed air blown into the tube from the mouth of the user. "The blow-tube is really the legitimate prototype of the gun."

Illustrative Lantern Slide. No. 23, showing sling of Hupa Indians, dissected. (From the Origins of Invention, by Mason.)

62. **The Bow and Arrow.** The bow and arrow is of such great importance as to be worthy of lengthy discussion. As had already been stated it formed the principal missile weapon of mankind for many tens of thousands of years; in fact down to some time after the invention of gunpowder a few hundred years ago.

The bow has been made of several different shapes, types and details of construction. The principal types are as follows:*

1. *Plain or "self" bow.* This is made in each case of the best wood for the purpose that each country furnishes, hard wood being used in the temperate regions, and palm wood in the tropics. The wood is carefully selected by the savage craftsman, and is then carefully shaped and bent into the exact form desired. It is frequently treated with some material rubbed into its fibres, and often covered with sinew or other material to prevent splitting. The cord was originally made of sinew, or of woven vegetable fibre.

2. *The sinew lined bow.* In the United States, west of the Rocky mountains; "this consists of a bow or frame work of yew or other soft wood, on the back of which is plastered, by means of animal glue, a mass of finely shreaded sinew. This is done so skilfully as to give the appearance of bark. The sinew must be glued down with greatest care to avoid weakness on one hand, and a backward breaking strain on the other."

3. *The sinew corded bow, as made by the Esquimo.* "The essential principle of this invention is by means of a cable of sinew, twine, or braid, to convert the breaking strain of a bit of drift-wood into a columnar strain." The sinew and wood are so combined—the sinew on the back of the wood—that the rigidity is supplied by the wood and the elasticity by the sinew. The bow may be regarded as a compound beam, the sinew taking the tension stress, and the wood the compression. Ivory levers by which the sinew cords can be twisted are provided by the Esquimo for tightening and loosening the sinew cords. After these cords are wound, the levers are withdrawn, and unwinding is prevented by a strip of raw-hide passed through the cords many times and made fast to the wood.

4. *The composite bow.* Mason states that in tribes of the Plains Indians and Eastern Esquimo, "these may be made of wood, antler, horn or bone. The Sioux type consists of three pieces, the limbs of horn, the grip of wood, made in the shape of a Cupid's bow. These parts are held together by sinew twine and covered with skin to conceal the joints."

Mason also states that bows of the Esquimo type are ruder, and that among them, the material being very scarce, the compound bow may be constructed of pieces of hard drift wood, whale ribs, or even of Walrus ivory.

The composite or built up Asiatic bow belongs to the barbaric culture stage. Good examples are the "Kung" bow, of China, the "Tatar" bow, and the famous Turkish reflex bow. These are compounded of (1) the self bow as a base; (2) the separate arms of the compound bow; (3) the sinew

*See Mason's "The Origins of Invention," page 384.

backing or a substitute; and (4) the covering of snake skin, or bark, or buckskin, to conceal the joints. It is argued that the Tatar form of bow was in every day use around the besieged city of Troy, and that the Scythians contributed this type to all the classic nations."*

Illustrative Lantern Slides. No. 41. Sinew lined bow, with arrows and quiver, of a Hupa Indian. From Mason's *Origins of Invention.* Nos. 5819 and 5820. Comparative dimensions of oriental reflex, composite bows, Chinese, Tartar, Indian, Persian and Turkish. Nos. 5814 and 5813. Parts of a Turkish composite bow, viz., sinew back, thin wood center, and horn face on bow-string side. No. 5812. Turkish reflex bow, and arrow. No. 5816. Method of stringing Turkish and ancient Grecian reflex bows. All the above from Sir Ralph Payne-Gallwey's *Projectile Throwing Engines of the Ancients.*

These oriental bows were very powerful and could throw a short, light, flight arrow to almost incredible distances. The Turkish Ambassador to England shot a flight arrow 482 yards in 1795, and Sir Ralph Payne-Gallwey reports records on Turkish columns at Constantinople of 625 to 838 yards. He also reports that the longest shots made with the famous English long bow were about 335 yards.

The arrow is in some respects even more difficult to manufacture than the bow. Arrows have been made with many different details among different savages. In America it is stated that each tribe of savages and each kind of hunting and fishing, and each region, has its peculiar arrow.

The plain arrow consists simply of head, shaft, feathers and nock.

The head is usually made of stone, among savages, and in the most advanced savage culture stage is very frequently barbed. It was usually fastened to the shaft by lashings, the shaft being split at the attachment, but many different forms of attachments have been used.

The shaft must be perfectly straight, and it was often necessary to straighten it artificially.

In the arrangement of feathers, and method of attaching the same, many different details have been employed. In some cases the feathers are attached at a slight angle so as to cause rotation of the arrow.

Mason states that the most complicated form of arrow in America was the sea otter arrow of the Alaskan Indians, which may be described as follows: "Shaft of cedar, thirty inches long and three-eighths of an inch thick; fore-shaft of bone, six inches long; feathers, three, daintily laid on and trimmed; cock-feather; white; neck, large, bulbous and deeply notched; head, a dainty little barb of bone or native copper, fitting loosely into the outer end of the fore-shaft, pierced on end for the fastening of a braided martingale or sinew cord; martingale tied into the head at one extremity, and at the other divided for three feet into two parts, the end of one part tied to the shaft near the fore-shaft, the other end made fast near the feather. When this shaft is shot into an otter, the little barb is driven quite under its skin and is pulled from the foreshaft. The sinew martingale unwinds, the bone fore-shaft sinks in the water, the telltale feathers bob about in the air, the shaft acts both as drag and buoy aiding the hunter to follow and retrieve his game."

Illustrative Lantern Slides. No. 29. Dissection of a Hupa arrow, showing different parts, different styles of head attachments, etc. From Mason's *Origins of Invention.* No. 5815. Turkish arrow, nock and feathers. No. 5818. Turkish thumping. No. 5817 Turkish horn groove. The above from Gallwey.

63. **Savage Protective Armor.** Just as the blow-gun may be considered the prototype of the largest and highest powered cannon of the present day, so the shield and rawhide armor of savages may be considered the prototype of the steel armor of the modern battleship.

Savage protective armor may be divided into two types:

1. *Devices held in the hand.* Under type 1, we have, first, the *parrying stick.* According to Mason, the Dinkas used parrying sticks of elongated

*Mason, page 385. See also Sir Ralph Payne-Gallwey's "Projectile Throwing Engines of the Ancients.

spindle shape, the bulbous central portion being hollowed out, and having a grip for the hand. Parrying-bows have been used for the same purpose. On Drummonds Island, in the Kingsmill group, the inhabitants use, it is stated, kirri-sticks for warding off stones.

More effective than the parrying-stick is the *shield,* which, according to Lane Fox, as quoted by Mason, was developed from the parrying-stick. The gradual widening of the club in the center, and the covering for the hand, led, at last, to the long narrow shield, which later led to the broad shield covering the body. Shields are made of wood, or of rawhide from large animals An extensive discussion might properly be devoted to the many varying kinds.

2. *Devices worn on the body.* This type finds its most primitive illustration in the rawhide armor made from skins of large animals, and worn by many savage tribes. Of later development are armors made of woven fibre and cocoanut fibre or with rods of wood laid parallel, woven together and fitted to the body, as in the case of North American and Asiatic tribes, and, finally, of quilted cotton armor, such as was found in Mexico in the barbaric culture stage.

Illustrative Lantern Slide. No. 2, showing slat armor from California. (From Mason's Origins of Invention).

64. **Savage Tools.** All savage implements not used as weapons are here included under the head of tools. Adrian de Mortillet, as quoted by Mason,* makes a classification of simple tools, as follows:

I. **For Cutting. Edge Tools.**
Working.
1. By Pressure.....Knives, double edged tools, shears, planes.
2. By Shock.....Axes, adzes, chisels, gouges.
3. By Friction.....Saws.

II. **For Abrasion and Smoothing.**
Working.
1. By Pressure and Friction.....Scrapers, gravers, rasps, polishers, smoothers, burnishers, whetstones, grindstones.
2. By Shock.....Hammers, working on the principle of bush hammers.

In wood working, fire is an efficient element in abrasion.

III. **For Fracturing, Crushing, Pounding.**
Working.
1. By Pressure.....Chipping and flaking Instruments.
2. By Shock.....Hammers, pestles.
3. By Friction.....Grinding apparatus, mills.

IV. **For Perforating.**
Working.
1. By Pressure and Friction.....Needles, prickers, awls, drills of all kinds.
2. By Shock.....Punches. Picks.

V. **For Grasping and Joining.**
1. Tongs, pincers, vices, slamps, wedges.
2. Nails, lashings, glues.

All of these tools have their examples among savage implements.

In many of the lantern slides already shown, knives have been illustrated, as made of stone.

Some savage tribes had no other knives than pieces of hard wood, such as bamboo cane. The outer rind of this wood when recently split is very sharp.

*Origins of Invention, page 31.

Savages had no shears, working like those of civilized people. There is only one cutting edge, and that is used in the same manner as the modern saddlers cut skin, by holding the article to be cut against some fixed edge.

Savages have no planes corresponding closely to the modern plane, or jack plane, but the drawing knife and the spoke shave are directly descended from aboriginal implements. Axes, adzes and chisels are exemplified by stone implements. However, there is not a very sharp distinction made between them. The very same stone blade may be mounted differently, to form either an ax, or an adze, or a chisel. The savage chisel was shoved from the workman and usually was not struck with a mallet. Nevertheless, the tendon and mortise, which may be regarded as peculiarly the work of the chisel, were made in the highest savage culture stage.

Savages used wedges for splitting boards from logs, rather than saws for ripping. For cutting across the grain, on the other hand, the saw was one of the oldest tools known. In some instances aboriginal saws were made by inserting bits of stone or the teeth of sharks in a groove in a handle. In other cases stone saws with jagged edges were used; and in still other instances sand was used in connection with a thin piece of stone, wood, or other soft material.

Scrapings, gravers, whetstones and grindstones are common savage implements, as are also hammers, both for abrasion, and for fracturing, crushing, and pounding.

Chipping and flaking instruments have already been described and discussed. The mortar and pestle were devised at a very early date, and extensively used in the preparation of seeds for use as food.

Needles and awls were made from pieces of bone and other materials.

Drills were provided and operated, exactly on the principle of fire drills, as already described in Article 51.

Various types of tongs, and pincers, and wedges were used by savages. The prehistoric vice and clamp often consisted of two pieces of wood lashed together by rawhide.

In fact, savages made special use of lashings. Rawhide possesses the quality of greatly shrinking, and by its use very tight lashings were possible.

Savages invented and used many different kinds of glue.

For polishing, grass containing silex, very smooth stones, ochres laid on buckskin strips, or the hard hands were used. In many cases, all marks of chipping and sawing were obliterated from stone tools, even in the case of the hardest materials, by this process. Savages also made considerable use of burnishing materials and of varnishes and oils, to fill the grain of the wood, and give a better shine.

Paints were used by savages, but mostly for decorative purposes.

Illustrative Lantern Slides. No. 71. Stone scraper. (From Evans' Stone Implements). No. 59. Two flint knives, and flint borer. (From the Story of Primitive Man, by Edward Clodd.) No. 76. Flake saw, and examples of stone adzes and picks. (From Evan's Ancient Stone Implements.) No. 24 Mortar and grinding stone, illustrating the earliest grinding stone for corn. (From Primitive Man, by Hoerness.) No. 73. Hammer stone and bone needle, found in Kent's Cavern, England. (From Evan's Ancient Stone Implements.) No. 15. Shell spoon, showing method of hafting. (From Mason's Origins of Invention.) No. 54. Necklace of jet, studded with spots of gold, found in a barrow, in Ross-shire, England. (From Evans' Ancient Stone Implements.) No. 25. Wrench, for straightening wood or bone. (From Mason's Origins of Invention.) No. 47. A primitive Esquimo vice. (From Mason's Origins of Invention.)

CHAPTER VI.

SAVAGE MANUFACTURE AND INDUSTRIES, TRANSPORTATION, NAVIGATION, ENGINEERING AND ARCHITECTURE.

65. **Treatment and Uses of Hides and Sinews by Savages.** The art of tanning was not known to peoples in the savage culture stage. They had,

however, many processes of treatment which were given to hides to prepare them for different uses. Among the western Indians, rawhide was prepared by first removing the hair, by soaking in water containing wood ashes or other alkaline substance. The skin was then cut in the desired shape and put on a frame while green. When it became dry, it hardened, and according to Mason became nearly as strong as iron. It is stated that many miles of rawhide were prepared by each savage. By other methods of treatment, buffalo hide could be made smooth and pliable. Similarly, deerskin could be worked into smooth and pliable buckskin, by a process known to all Indian tribes.

From the skins of animals, clothing was prepared for all savage races. Skins were also made into shields and armor, into cord, and used in many other ways.

The uses of sinew have already been discussed in connection with bows, arrows, etc. The tendons of animals were shredded, and very extensive use made of the sinew thus produced.

66. **Uses of Fiber by Savages.** As has already been indicated in many places in the preceding discussion, very extensive use was made by savages of fibers of all kinds, both animal and vegetable. Grasses, cocoanut fiber, the inner bark of trees, cotton, wool, reeds, rushes, and splints of wood, are examples of fibres extensively used by savage people. Some fibres were woven into baskets and mats, without previous spinning into threads. They were also braided into cords, or spun into threads, and used in mat making and in the weaving of cloth.

67. **Savage Manufacture of Mats and Baskets.** Mats and baskets were the simplest woven products to be produced by savages. From splints of wood, willow osiers, braided cord, etc., many different types of mats and baskets were produced. By the experience of many people, extending through long periods of time, many different woven stitches were devised. In the rudest form of baskets, the work is very crude, while in higher forms, baskets were made water-tight with no other material than woven fibers, and stitches were used of such intricacy as to constitute practically the beginning of lace making.

Mats were used for clothing, for shelters and for sails.

Baskets were used for transportation, for storage of seeds and other food, and even for the cooking of food. In a water-tight basket, water could be boiled by immersing red hot stones, without injuring the material of which the basket was made.

Illustrative Lantern Slides. No. 45, showing plain weaving of cedar bark on the coast of British Columbia. This illustrates the plainest type of rectangular weaving of strands of bark. No. 17, showing diagonal weaving, common in many American tribes, being a variation of the plain rectangular stitch. No. 38, showing the detail of coiled basketry from the southwest United States. No. 10, showing detail of the "birdcage" stitch in basketry, in which two horizontal weft strands were twined about the vertical warp strands. No. 5 gives detail of the Aloutian basketry, showing twine stitching with split warp strands. No. 21 shows a wicker basket of the coarsest type as made by Zuni Indians, with large scale view of the detail. No. 40 shows the Pima burden basket, Arizona, a basket of the highest and most ornamental type, with the stitch so elaborate as to constitute the beginnings of lace making. The detail of the stitch is shown in the view. (All the above are from Mason's Origins of Invention.) No. 88, a Pima basket maker. No. 87, Hopi maiden weaving a plaque. (Both the above from Dorsey's Indians of the Southwest.) No. 81, Cliff Dwellers' sandals, more than 1,000 years old. (From Lipps' The Navajos.)

68. **Savage Manufacture of Cloth.** The next step in advance beyond the weaving of mats and baskets would be the manufacture of cloth. This step has universally been attained in the most advanced savage culture stage.

In the manufacture of cloth, the process may be divided into two parts, spinning and weaving, which will be taken up in order.

In *spinning,* the object is to produce a continuous thread or cord by the intertwining of animal or vegetable fibers. Undoubtedly the first cords were produced simply by hand twisting of fibers, and in some cases this process may still be seen in use by savages. After learning to twist cords with the fingers, a further step would be to twist with the palm of the hand, keeping the thread or cord between it and the thigh, as is still practiced by some savages. Some method of storing the twisted cord, so as to prevent its untwisting was necessary and this was done by coiling the cord on a stick, which resulted in the development of the spindle.

At an early date it was discovered that the spindle itself could be made to rotate and do the spinning, if it were provided with an arm or disc to furnish sufficient momentum to keep up the whirling movement. Hence, the complete spindle, as developed by savage tribes, consisted of a shaft of wood, upon which was placed a simple whorl in the form of a perforated circular disc of stone or other heavy material. These spindle whorls are found in great numbers among the relics of prehistoric savages, and are found in use among modern savages.

With the development of the spindle, the process of spinning consisted of taking in the hands a strand of the fiber which was to be spun, attaching one end of the strand to the upper end of the spindle, imparting to the spindle a rapid rotary motion, which is kept up by the spindle whorl, and allowing this rotation of the spindle to twist the cord and draw it through the hands, which control the rate of spinning, and the diameter and hardness of the cord. When the spindle reaches the ground the cord or thread already spun is wound upon it. A new attachment of the fiber to be spun is made to the upper end of the spindle and the process continues. Practically the same process of spinning devised by savages was used throughout the entire barbaric culture stage, and even until a recent date in the civilized stage.

Illustrative Lantern Slides. No. 28 shows a Zuni Indian spinning woolen yarn by use of a spindle such as has been described. (From Mason's Origins of Invention.) No. 64 shows two spindle whorls as found in England as relics of prehistoric savages. A jet button is shown on the same slide. (From The Story of Primitive Man, by Edward Clodd.)

The second step in the process of the manufacture of cloth is *weaving* the spun thread or cord into cloth. The development of cloth weaving resulted naturally from the weaving of basketry and mats, but the threads, not being stiff, required some convenient method of support and manipulation, and this led to the gradual development of the *loom.*

Mason, in his Origins of Invention, page 246, gives the following description of the rudest savage looms:

"In many parts of the world, savages set up frames, very much like the old fashioned quilting frames, only of very rude sticks laid parallel on the ground or fastened to some stable objects, just as far apart as the fabric is to be long. In a continuous long spiral they wind the warp yarn backward and forward about these sticks until the warp is as wide as the blanket or other fabric is to be. The threads are thus adjusted at equal distances on the sticks above and below. A long rod is then laid against the warp and by means of a continuous yarn this harness is made fast to the warp threads farthest from it, the back threads, if the loom is standing. This can be done by simply winding the yarn about the stick and passing it between the front warp fillets and around the back ones, as a hurdle or heald, until every thread is attached to the harness stick. The yarn of the weft is wound on a long stick by wrapping it around one end once or twice, carrying it to the other end, wrapping it there, and so on, backward and forward until enough is wound. The weaving consists in drawing the harness stick toward the weaver which pulls the back set of warp threads forward between the other or front set. The primitive shuttle is then passed between the two sets of warps, the end of the yarn having been fastened to the outside warp

and enough yarn unwound to go across. With the two hands, this first weft fillet is drawn taut, and any inequalities adjusted with a pointed bone or stick, and then is driven home by a wooden sword, lightly, if the texture is to be plain, with some force if it is to have a corded appearance. The sword is then withdrawn, the harness stick slackened, the back set of warp thread forced into their places by the sword and another weft thread carried across. This constitutes the action of the most primitive loom."

Later, more complicated apparatus was developed, by which patterns could be readily woven into the cloth, and by the introduction of colored threads ornamental textiles were produced.

Illustrative Lantern Slides. No. 34. Zuni woman weaving a blanket. This slide shows clearly the details of a primitive loom, as described by Mason above. (From Origins of Invention, by Mason.) No. 21. A Navajo weaver. No. 31 Navajo weavers. Showing Navajo Indians at work with primitive looms. (Both above from Lipps' The Navajos.)

69. **Savage Manufacture of Pottery.** Another manufacturing industry which has developed among all savage tribes of the higher culture stage is that of the manufacture of pottery. It is surmised that the manufacture of pottery developed from the use of basketry for storing and cooking food. It has already been stated that in water-tight baskets, such as are woven by many savage tribes, food can be cooked without injuring the basket by introducing red hot stones into the water. In an effort to make a vessel which would hold water and not be injured by fire, a natural step would be to cover the basket with clay. Experience would then gradually teach savage people that this clay would burn hard and be capable itself of acting as a water-tight vessel which would stand fire. That this is the method of the early development of pottery is evidenced by the fact that the earliest lines of ornamentation resembled, in many cases, the impress of woven basketry upon the soft clay.

There are three methods in use by savage tribes for forming clay vessels to be burned into pottery: First, by molding; second, by coiling; third, by modeling.

The method by *molding* consists in forming the clay vessel upon some mold, such as the interior or exterior of a basket. If the mold is not so constructed as to permit it to be removed, it would disappear in the process of burning.

In the method of *coiling*, the clay is first made into a series of flexible ropes. Very often a shallow basket mold is used for starting the vessel. In the interior of this basket mold the clay is placed, and when the top is reached, the shape of the vessel is continued by coiling the rope of clay around and around, splicing it as the end of each individual piece is reached.

The first clay vessels were in many cases broad and shallow and open at the top. These have many disadvantages for the storage both of water and solid materials. Gradually savage peoples came to close in the tops of their clay vessels.

After the vessel was completed in the soft clay by the coiling process, the interior and exterior were smoothed out by hand scraping or by suitable tools. At first the interior alone was smoothed, but later both sides.

In the third method, that of *modeling*, the clay was shaped by hand, without reference to a mold, just as a sculptor models a figure from the raw material.

Savages did not invent the potter's wheel. The nearest they came to it was the forming of their clay vessels in the interior of a basket, or other mold, which may be regarded as a stationary potter's wheel.

The earliest pottery found is rude in shape and ornamentation. Many savages learned to improve the external appearance and imperviousness of their clay wares by dipping them into a "slip" composed of thin clay, after the form of the vessel was completed. They gradually learned that different clays would burn different colors. Ornamental patterns came to be impressed

upon the soft clay to remain in the burned work, and by the use of different clays and "slips" colored patterns could be produced.

Illustrative Lantern Slides. No. 80. Pottery from Auvernier, showing very rude pottery of early European savages. (From the Story of Primitive Man, by Edward Clodd.) No. 42. Clay vessel from Neolithic Swiss Pile Village Attersee. (From Primitive Man, by Hoerness.) No. 43. Coiled Pottery, showing manner of forming vessel before burning. No. 4. Painted decorations from vase from Moki Pueblo, showing ornamentation of savage pottery. No. 20. Pottery bowl, from San Juan, southwest United States, showing decorations. (All from Mason's Origins of Invention.) No. 91. A Hopi pottery maker. No. 90. View of the firing of pottery by southwest Indian in a primitive kiln. No. 89. Showing an Indian at work decorating pottery. (These three from Dorsey's Indians of the Southwest.)

70. **Savage Implements of Agriculture.** Regular tillage of the soil was not used until the neolithic culture stage. The digging stick, which was, undoubtedly, the beginning of agricultural implements, and the progenitor of the hoe, spade and plow, was a sharp stick about six feet long, often hardened by fire. In many observed cases of modern savages, such digging sticks were almost the only implements used in their agricultural operations. Later on came the development of wooden spades, with a cross piece near the point for the foot. Hoes were also used by many savage people with blades of stone, shell, wood or bone.

Besides implements for the cultivation of the soil, others were needed for harvesting the crop, but not many special tools were invented or used for this purpose.

71. **Land Transportation among Savages.** Land transportation among savages was almost entirely by direct carriage by men, women and children. Wherever commerce became sufficiently established to require comparatively regular transportation of loads, porters were employed, and the long lines of such porters in savage Africa, or the wild regions of other savage countries, may be regarded as the predecessors of the long freight trains on modern railways.

Many ingenious carrying bands, or harnesses, and methods of supporting heavy loads with the least effort and discomfort were invented by savage porters, and the burdens they could carry seem enormous to their civilized successors.

Among modern savages, some use is made of beasts of burden, such as that of horses by the American Indians, who use them for direct carrying of burdens and to drag the travois. The travois consists of poles supported at one end by the horse and dragging at the other end upon the ground, upon which the burden is placed or people ride. However, the Indians were not in possession of horses prior to their contact with Europeans, so that this can hardly be considered an example of savage transportation methods.

The Esquimo transportation on sledges hauled by dogs was, however, an independent savage development. The Esquimos show much ingenuity in the construction of their sledges and in the harness for the teams of dogs.

Illustrative Lantern Slides. No. 8, showing parbuckle and carrying strap combined, as found in northeast Asia and British Columbia. No. 60. Complete outfit for a California acorn gleaner and miller, showing, besides other articles, the headband, and basket for carrying acorns. (Both from Mason's Origins of Invention.) No. 23.1, a carrying basket. No. 21.1, Karen boy of Burma, carrying breadfruit. No. 19.1, San Carlos, Apache woman carrying water in a wicker jar lined with pitch. No. 18.1, Zuni woman supporting a jar of water, also showing head or milkmaid's pads. No. 17.1, breast yokes used in hitching the Esquimo to his load. No. 16.1, Napo Indian carrier of Ecuador. No. 12.1, Washington negro carrying burden, also showing carrying basket of the Caragador. No. 13.1, carrier of the Sandwich Islands. Also shows

carrying net and frame. No. 14.q, carrying frame and coffee carrier of Rio. (Above nine from Mason's Human Beast of Burden.)

72. **Navigation Among Savages.** No savage tribes have been found who have not some knowledge of navigation.

The first rude device among savages, was, undoubtedly, the single log. Later several logs were bound into a raft, and among some tribes rafts developed to such a stage that they were driven by sails, and the users ventured out of sight of land upon them.

The next step in navigation in advance of the raft was the construction of dug-out canoes. These were hollowed out of trunks of trees, by fire, and the use of stone axes. At first no attempt was made to give an artificial shape to the canoe different from that of the tree from which it was made. Both ends, for example, were cut squarely across. Later on, the ends were carefully shaped, so as to afford the least resistance to water, and by the use of water and heat the sides of the canoes were shaped. It is stated that in the best types of canoes, the shapes could not be improved upon by a modern boat-builder.

A still higher stage of development of boats is found in the bark canoe, of the American Indians and other tribes. Such boats consist of a water-tight sheating supported and shaped by a frame, and are much more complex in structure than the simple dugout. It would be hard to improve upon the birchbark canoes of the American Indians for lightness and gracefulness and complete adaptability to the needs of the tribes who use them. An early traveler has stated that in some cases the canoes were made so small and light as to be carried continually with parties of Indians, ready for use whenever a considerable body of water was encountered.

The highest type of construction of savage boats is probably exhibited by the canoes used in some of the Pacific islands. Here, each boat was constructed with a keel, and with planks hewn out of timber. In some cases these planks were dressed so that a vertical cross-section would be something like the cross-section of a modern channel-iron and they were fastened by sewing with cords passed through holes within the flanges. Thus the edges of the planks were formed in such a way that the sewing did not show at all on the outside of the boat. Such boats came to be provided with sails of matting or hide, and with outriggers to prevent capsizing. Mason states, on page 361 of Origins of Invention, that the Polynesians made many voyages with such boats between Tahiti and Hawaii, a distance of 2300 miles, before the discovery of America by the Europeans.

Sails represent the highest development of motive power in savage navigation. The usual propelling power is the paddle, but some tribes of Esquimos have devised a rude row-lock, to take advantage of the principle of the lever.

Illustrative Lantern Slides. No. 68. Dug-out canow canoe with square ends from one of the Swiss Lake Villages. (From the Story of Primitive Man, by Edward Clodd.) No. 35. American "bullboat" or coracle. No. 26. Forms of paddles in America. No. 12. Primitive row-lock, or Esquimo lever device. No. 16. Malayo-Polynesian canoe and outrigger, with which the Pacific ocean was explored in the seventeenth century, A. D. This canoe is made of planks as described above, and is provided with mast and sail. (From Mason's Origins of Invention.)

73. **Mathematics, Astronomy and Systems of Measurement Among Savages.** All savages have some idea of numbers, although some low tribes have been studied which have no names for numbers higher than two. Practically all systems of numbering have been based on the number of fingers on the "two hands," which has given rise to the use of the decimal system. In a number of languages the same word means "hand" and "five," and in others ten is designated by "two hands." There seems, however, to have been a tendency among savages to count in twenties prior to counting in hundreds. The more advanced savage tribes have methods for expressing quite high numbers. It is stated that the Hawaiians had special words for four hundred,

four thousand, forty thousand and four hundred thousand.

For making records of numbers, many savages have used tallies of straw, or pieces of wood, or notches on sticks. It is stated that among the Hawaiians, who represent the highest stage of savage development, a full record was kept in this way for the purposes of tribute, or taxation. The numbers of dogs, hogs, pieces of sandal wood, etc., which each man was to furnish were well defined.

In general, all early measurements are based upon the human body and its work.

As units of distance, we have the fingers, the span, the length of the forearm, whole arm, extended arms, the foot, the pace, the day's journey. From these elementary ideas our present units of distance have been derived.

The dimensions of arrow and spear, and many other savage implements, bear some regular relation to the size of the person using them.

In the matter of weights, the load which a man could carry was the unit of measurement.

Volume in some cases was counted by handfuls, basketfuls, bucketfuls, canoefuls, etc.

Savages know very little of astronomy, but in their highest culture stages the priestly classes made observations of the stars, moon and sun over sufficient periods of time to ascertain the periodical recurrence of certain phenomena, such as the appearance and apparent location in the heavens of the moon and the sun, by which they came, eventually, to fix the lengths of months and years.

It is stated that in the case of Pueblo Indians, openings were left in the east walls of certain houses, and marks placed on the west walls, in such a way that whenever the rising sun struck through the opening and hit the mark it was known that a certain day of the year had arrived, from which their yearly reckoning was dated.

74. ENGINEERING AMONG SAVAGES.

Uses of Mechanical Principles. In a broad sense, all that we have been discussing in Part II has to do with engineering among savages. In article 74 there will be taken up only some direct applications of mechanical principles for the use and convenience of man.

It may be stated first of all that savages acquired by long experience a practical working knowledge of many mechanical principles. Among these there may be enumerated the inclined plane, the lever, the wedge, the use of rollers to reduce friction, the column, the beam, and the block and tackle.

Illustrative Lantern Slides. No. 63. Primitive engineers, showing Thlinket Indians landing a cedar log for communal house. The log is supported by rollers and is being hauled up a sloping beach constituting an inclined plane. The work is being done by a large number of men pulling in unison on a cable. The frame of the house has already been partially erected, showing the use of the column and beam. Nearby are wooden planks which have been split from logs by wedges. No. 30. The first tackle, showing Esquimo landing a walrus. They have no pulleys but have attached stout, smooth pegs to a large mass of rock. They have led rawhide lines around these pegs and to the walrus in such a way that when pulling upon the lines the power is multiplied just as it would be by a modern block and tackle. (Both the above are from Mason's Origins of Invention.) No. 7.1, Navajo jewelry and silverware. No. 5.1, a Navajo silversmith. (Both above from Lipps' The Navajos.)

Roads. Savages did little toward the construction of permanent roads. However, they had permanent trails which were used for generation after generation, the marks of which still show in some of the settled portions of the United States. These paths or trails were located in such a way as to avoid the principal topographical obstacles to travel, and in some instances

a little work may even have been done upon them in places to make them more passable.

Transportation of burdens was by human carrier, in general, but with some exceptions, as above stated.

Bridges. Savages have done comparatively little along the line of bridge engineering. In some instances they constructed rude foot bridges across streams by driving piles, between which logs extended, a railing being often provided at the side. In other cases they spanned streams with rude suspension bridges, a span being hung from rude cables of osiers or other fibers.

Fortifications. Considerable has been done by savages in the way of fortifications. The great mounds erected by the Mound Builders have already been mentioned, one of which contained nearly three quarters of a million cubic yards of earth. Earth mounds and walls, which were surrounded by palisades, were used in many instances. Among more advanced savages, stone masonry walls were built. The cliff dwellings of Pueblo Indians are instances in point.

Irrigation Among Savages. In many instances savages have carried on agriculture to obtain food supplies, and they have been driven to overcome the lack of moisture in arid regions by irrigation. Mason gives special credit to the Pueblo Indians of the arid regions of the United States for irrigation works. He quotes Mr. Hodge, who states that they engaged in agriculture on a large scale by this means in the valleys and on the mountain slopes, especially along the drainage of the Gila and the Salado rivers, in southern Arizona. The arable tract of the Salado, alone, is stated to comprise about four hundred and fifty thousand acres, of which the ancient inhabitants irrigated at least two hundred and fifty thousand acres. Lines of main irrigation ditches may be readily traced, some of them as long as fourteen miles. The remains of flood gates are found, and of reservoirs for storage, one example being 250 feet long and 15 feet deep.

75. **Savage Architecture.** Architecture among savages began with their construction of huts and other dwellings. Some existing tribes never erect huts or tents. They go no further than to put up mere shelters, open at one side. Among these many may be mentioned the Bushmen of Africa, the Australians, and the Fuegians. The Bushman digs a hole at the side of a bush or sets up a small mat supported by sticks. "The Australian makes a little shed with bark or bushes. The Alforese, of the interior of Ceram, often spends his night in a treetop, where he makes a little roof to keep him dry when it rains. The low savage of the interior of Sumatra, Borneo and Luzon, sleeps in the top or hollow log of a tree."* Prehistoric man in England and many other countries used caves as dwelling places.

Savages have gradually risen from the culture stage in which they erected no permanent dwellings, to that of wigwams and temporary huts; and beyond that to fairly permanent villages and houses; and in the case of the Northwest Indians of the United States, and the Five Nations and other tribes, to large wooden communal houses; and finally in the case of the Pueblo Indians of southwestern United States, to large permanent masonry communal houses.

Different tribes have different architecture, so that in Africa the tribe can be recognized from the styles of dwellings erected.

The materials used for savage dwellings vary from hides and mats of vegetable fiber, and poles and leaves for thatching, to solid wooden houses, adobe construction, and finally stone masonry.

The Esquimos build huts of snow and ice laid up in the form of a dome, and furnish perhaps the earliest culture stage utilization of the principle of the arch. However, the permanent houses of the Esquimo, made of stone, do not use the principle of the true arch, but the roof is formed by cantilevering it in from the side walls, using small projections in successive courses.

*Hittell, Mankind in Ancient Times.

Savage architecture went beyond the stage of pure utility, evidenced by the construction of dwellings. At an early stage savages acquired some idea of existence after life, and began to pay funeral honors to their deceased relatives and friends. From this rude beginning religious ideas showed a gradual development until in the higher stages of savagism there is a regular worship of gods, to whom medicine men dedicate their services. This development may be traced to some extent by monumental constructions. The graves of savage peoples, as well as of barbaric and civilized races, have furnished much evidence as to the culture conditions of the people for whom they were made. In many cases the mounds erected by savages are for burial purposes, and in other cases for religious worship. In early culture stages large stones were placed in position by the graves, to serve for monuments as in the case of dolmens of Europe, and after a time the stones came to be placed in more regular positions. Such monumental construction, of natural stone, uncut, may be supposed to have reached its culmination in the famous Stonehenge, England.

Illustrative Lantern Slides. No. 83. Group of sacred stones in the Deccan. (Reference not ascertained.) No. 48. Holed Dolmen in Circessia, India. The holes in the dolmens were left for th free ingress and egress of the spirit of the departed. (From The Story of Primitive Man, by Edward Clodd.) No. 37. Dolmen in France. (From The Story of Primitive Man, by Edward Clodd.) No. 55. Close view of the Trilithons at Stonehenge, England. (From The Story of Primitive Man, by Edward Clodd.) No. 84. Stonehenge, England. (Reference not ascertained.) No. 86. An ancient adobe. No. 92. Pueblo of Tesuque. No. 93 General view of Santa Clara Pueblo. No. 94. One of two house pyramids, Taos. No. 95. House walls exposed by recent excavations. Pueblo Banito, Chaco Canyon. No. 96. General View of Santa Domingo Pueblo. No. 97. From a Zuni housetop. No. 98. Towers and Sections of Masonry, Mt. Elmo and Chaco Canyons. No. 99. House with balcony, Mesa Verde, Colo.

TRIBES OF THE HIGHEST SAVAGE CULTURE STAGE.

TRIBES	Sail Canoes	Slavery	Nobility	Despotic Chiefs	Temples	Hereditary Priests	Tribal Deities
Iroquois	N	N	N	N	N	N	N
Creeks	N	N	N	N	N	N	N
Dakotas	N	N	N	N	N	N	N
Kaffirs	N	Y	N	Y	N	N	N
Maoris	Y	Y	N	Y	N	Y	N
Samoans	Y	Y	Y	Y	N	Y	Y
Fijians	Y	Y	Y	Y	Y	Y	Y
Tongans	Y	Y	Y	Y	Y	Y	Y
Hawaiians	Y	Y	Y	Y	Y	Y	Y
Tahitians	Y	Y	Y	Y	Y	Y	Y

TRIBES OF LOWEST SAVAGE CULTURE STAGE.

TRIBES	Four Numerals	Dogs	Canoes	Huts	Tillage	Chiefs	Pottery	Polished Stone	Cloth	Funeral Rites
Bushmen	N	N	N	N	N	N	N	N	N	N
Lowest Californians	N	N	N	N	N	N	N	N	N	Y
Tasmanians	N	N	N	N	N	N	N	N	N	Y
Lowest Australians	N	Y	N	N	N	N	N	N	N	Y
Andamanese		N	Y	N	N	N	N	N	N	
Fuegians		Y	Y	N	N	N	N	N	N	N
Drift Europeans		N			N		N	N		N
Echinus Aleuts		N			N		N	N		N
Hill Veddahs		Y	N	N	N	N	N	N	N	Y

No. 1.1, Cliff Palace, Mesa Verde, Colo. No. 4.1, a Navajo winter hogan. (Above eleven from Lipps' The Navajos.)

76. **Resume of Progress in the Savage Culture Stage.** Hittell, on pages 320 and 322 respectively, of Mankind in Ancient Times, gives the following tables illustrating common tests of the culture conditions of savages. In these tables "N" stands for No., "Y" for Yes, and a blank indicates that no information was available.

In Chapters 4, 5 and 6 a discussion has been given of engineering in the savage culture stage, of which a brief resume may now be made as follows:

The savage culture stage has occupied by far the greater part of the life of mankind, extending over a time which is probably measured by hundreds of thousands of years, and for a considerable fraction of the human race it is not yet ended.

As to the *industries,* savages developed to the highest possible degree of skill the construction of stone implements, and also made extensive use of wood, bone, shell, and ivory for the same purpose. They used earth and stone as materials of construction. In the higher stages of savage culture, they developed cloth manufacture, pottery and tillage of the soil.

As to *commerce,* they developed systems of barter.

As to *land transportation,* nearly all was by human carriers.

In point of *navigation,* they attained the construction of framed canoes. with sails, capable of traversing thousands of miles of the open ocean.

In *engineering,* they made use of many *mechanical* principles, and in some instances developed *irrigation* on a large scale.

In point of *architecture,* they rose to the construction of great mounds, and monuments of uncut stone.

In point of *government,* they rose from a condition of absolute anarchy to well organized tribes under despotic chiefs.

In *social institutions,* they rose from a state of individualism to a point of fairly elaborate social organizations.

In *religion,* they rose from a condition of practically no religious ideas, to the worship of tribal gods, and the dedication to such gods of the services of medicine men; and they set aside for such worship, in some instances, regular religious structures.

In *mathematics,* they rose to a definite system of enumeration, and in *physical science* to a more or less definite system of weights and measures, and to a practical working knowledge of a large mass of scientific phenomena. They did not attain to any correct idea of the real nature of these phenomena, but were prone to explain them as due to supernatural agencies.

PART III.
ENGINEERING IN THE BARBARIC CULTURE STAGE

CHAPTER VII.
OUTLINE OF THE BARBARIC CULTURE STAGE.

77. **Definition of Barbarism.** There is no sharp dividing line between the successive stages of progress in human culture. Except as invasion and conquest by peoples in different culture stages effect sudden changes, culture makes a gradual progress which, though, subject to more or less ebb and flow, tends to rise even higher. Hence it is not possible to assign definite boundaries to the different culture stages.

However, in the general progress of savage races there comes a time when the tribal organization gives place to national government, with a corresponding progress in other phases of culture. When this condition is reached, the systematic united efforts of great masses of men can be and are directed towards the carrying out of carefully formed plans. Social institutions became highly developed and settled, bringing about a division of labor which is favorable to the acquirement of skill in the various handicrafts, and which insure the permanent acquisition of all new knowledge acquired, or skill developed. This state of society brings about new conditions in engineering and general progress, and is, therefore, worthy of a separate name. It is this state of society to which we apply the name "barbarism."

In Article 76, a resume has been given of the achievements of the human race in savagism. We may now define barbarism as follows: The barbaric culture stage is that stage in which people first become organized into great nations, with higher developed governments, religions, laws and social institutions, including a division of industries into organized crafts.

The barbaric culture stage is marked, wherever development has occurred naturally, without strong external influence from higher races, by the use of bronze as the best material for cutting implements. It is also marked by the first development of great cities, by the first construction of great architectural monuments, by the first great engineering works, by the extensive development of commerce, and of navigation.

Barbaric governments become highly developed, with a despotic monarch at the head; also with an hereditary nobility or higher class, whose achievements and culture are above that of the mass of the people.

Religions become developed to the point of worship of great national deities. However, the great point which distinguishes barbaric from savage religion is the inclusion of systematic moral codes as a permanent feature of religions. In barbaric religions there is an organized priestly class, and great religious temples and monuments make their first appearance.

Social institutions, in general, become both complex and permanent, as compared with conditions in the savage culture stage.

Great industries are generally carried on in the barbaric culture stage by organized hereditary crafts. Often the members of the same craft live in the same portion of their city. Mechanical progress under these conditionns was neccessarily very much more rapid than during the savage culture stage, when each new discovery had to be made over and over again by countless different individuals, in many generations, before it became a permanent acquisition of the while race.

78. **The Barbaric Nations.** Hittell* enumerates the following barbaric nations of ancient and modern times: The ancient Mexicans, the ancient Peruvians, the Chinese, the Teutons, the Celts, the Hindus, the Chaldeans and Assyrians, the ancient Jews, the ancient Egyptians, the ancient Persians, the Phoenecians, the Etruscans, the Carthaginians, and the modern Mohammedans. In these notes we shall, for the present, omit special discussion of the Carthaginians, Estruscans, Jews, Teutons, Celts, and modern Mohammedans.

79. **Culture Stages of Different Barbaric Nations.** In our study of barbaric culture, it will no longer be possible, as in the case of savage culture, to give a general discussion of each phase of culture. It will now be necessary to devote a separate discussion to each barbaric nation. This fact marks clearly the distinction between savage and barbaric culture, as already pointed out in Article 77. It will therefore be convenient and desirable to study the different barbaric nations in order of their progress in culture, although this plan is subject to the disadvantage of making it necessary to study, first, nations which in point of time are much more recent than older barbaric races which attained higher advancement in culture. Following this plan, it becomes necessary, as intimated in Article 5, to consider first and second the ancient Mexicans and Peruvians, and last of all the ancient Egyptians, Chaldeans and Assyrians, although the culture of the Mexicans and Peruvians was many thousands of years later, in point of time, than that of the other races named.

In point of order of culture, the barbaric nations may be ranked approximately as follows:

First, and second, the ancient Mexicans and Peruvians; who were in the lowest known stage of barbaric culture, and had emerged from savagism at a comparatively recent date when Europeans came into contact with them.

Third, the Chinese; who, while having a continuous history which has extended back to some thousands of years B. C., have shown until recently

* Mankind in Ancient Times. Vol. II, page 9.

a wonderful absence of change in culture conditions. Without attempting to determine the rank of their culture, we will consider them next after the Peruvians.

Fourth, while the ancient Hindus did not, perhaps, exert any very great influence in mechanical lines upon the history of the world, yet they may be placed fourth in these notes, because of their great contributions to mathematics, literature and religion, and also because they are a branch of that great Aryan race whose Greek and Roman representatives were the first peopel to attain the culture stage of civilization.

Fifth, and sixth, the Chaldeans who inhabited the Euphrates Valley and the ancient Egyptians who inhabited the Nile Valley contest with each other for the honor of being the first people to emerge from savagism into barbarism. Archaeologists are still in doubt as to which of these two centers of culture was developed the first. Both the Chaldean and Egyptian cultures came into direct contact with the ancient Greeks, who later developed the first civilized culture. Hence, the Chaldeans and Egyptians had very great influence upon the development of European civilization, and in fact an unbroken continuity can be traced in the progress of culture from that first developed in the valleys of the Euphrates and Nile down to that of the present time. In connection with this development the Phoenicians and Persians were very important factors and will merit discussion in this study. Little attention, however, will be given to the other barbaric nations mentioned in Article 78.

80. **Chronology of Barbaric Culture Stage.** As has already been stated, the barbaric nations will be considered in part III approximately in the order of their culture condition, and not in order of point of time. It is desirable, however, that the student should have a clear idea of the chronology of the barbaric culture stage, and hence, some mention will be made in this article of the approximate dates of the culture of each of the barbaric nations.

Mexico. More or less definite records and traditions carry back the history of the race whom the Spaniards found in possession of the country at the time of the conquest of Mexico by the Spaniards in 1520 for several hundred years; or say, approximately to 1000 A. D. It is evident that the culture which existed at that time must have required a long period of development, probably by races preceding those found by the Spaniards.

Peru. Exactly the same statement may be made concerning the dates of the Peruvian culture as have just been made for Mexico. The Spanish conquest was in 1535. By tradition and record, the history of the Inca race has been carried back for several hundred years, and a long period of development is manifestly necessary for the state of culture attained by the races preceding this.

China. The Chinese is the oldest existing civilization. Its history goes back to between two and three thousand years B. C., and the culture condition of the people has undergone very little change during the entire four or five thousand years of its history. Confucius lived 550 to 471 B. C.

India. The Aryan race seems to have invaded India from the Northwest, at, perhaps, as early as 2000 B. C. The Indian culture has been continuous from that time down to the present. Buddah lived about 557-477 B. C. Alexander the Great conquered a portion of India in 327 B. C.

Egypt. The dates of Egyptian history are not accurately established. There seems to be good authority for assigning 4000 to 5000 B. C. as approximately the date of the first permanent records. Myers adopts 5000 B. C. At this date Egyptian culture had already attained an advanced stage, which must have required thousands of years of previous development. The history of Egyptian culture is continuous from the date already mentioned down to the conquest of the country by various foreign nations, and its final absorption into the Roman Empire, about 30 B. C.

Chaldea and Assyria. Many authorities believe that the ancient civilization of the Tigris-Euphrates Valley was the first in the world to reach a stage as high as the barbaric. There has been a dispute as to which was first developed, the Egyptian culture or that of the Tigris-Euphrates Valley. The fairly authentic dates in the history of these countries, as well as in Egypt, extend back to approximately 4000 or 5000 B. C., and at the time of the earliest established dates, civilization had already reached so high a stage that many thousands of years must have been required for its development.

The following outline is taken from a history syllabus for secondary schools, prepared by a special committee of the New England Teachers Association, pages 60-68.

Pre-historic, or prior to 3800 B. C.
The Chaldean Empire, 3800 B. C. to 1250 B. C.
The Assyrian Empire, upper part of valley, 1250 B. C. to 606 B. C.
Later Babylonian Empire, 606 B. C. to 538 B. C.

Persia. The Persian Empire succeeded the Babylonians and continued to the date of its conquest by Alexander the Great. The dates 558 to 338 B. C. are assigned to it by Myers.

Phoenicia. The Phoenicians were a maritime nation and had much to do with spreading the culture of the Nile and the Tigris-Euphrates Valleys throughout the Mediterranean region. Myers states that the Mediterranean was already dotted with the sails of the Phoenician navigators at the time to which our first knowledge reaches, say, about 1500 B. C. and Tyre still remained a very important city in 332 B. C. when captured by Alexander the Great.

Teutons and Celts. The Teutons and the Celts were barbaric people, to the north of the Roman Empire, throughout its entire history, who eventually conquered it in the 5th century A. D., and thus developed European civilization.

81. **Bronze.** As has already been stated a number of times, the discovery of bronze marked the transition from savagism to barbarism, in the case of many nations where culture developed naturally; without interference from contact with peoples of higher civilizations. Copper, the first metal to be used for tools and implements, was too soft to be of great service. Independently a number of peoples discovered, when they had learned to build fires hot enough to melt copper and other ores, that copper could be hardened by admixture of a small proportion of tin or zinc. In some cases lead or silver appear to have been added for the same purpose, although the addition of silver may have been merely accidental. The mixture of copper and zinc produced brass, and in the Bible and other books the original native words which meant bronze have in many cases been translated brass. It was the mixture of copper and tin, however, to form bronze, which gave to barbaric peoples their characteristic metal. Zinc and lead were sometimes used in conjunction with tin.

At first the proper amounts of tin to be added were not understood, and it was added in small and irregular quantities. Gradually more skill was acquired in the manufacture of bronze, and the properties of different mixtures were more thoroughly ascertained. Bronze was greatly superior to stone as a material for implements and weapons. The first bronze tools and weapons closely copied the shape of the stone implements of the older neolithic culture. More characteristic and suitable forms were developed in the later stages of the bronze culture.

Iron was undoubtedly discovered and used to a limited extent long before bronze went out of use as the principal metal. In some cases, for example, iron ax heads and cutting edges were mounted on bronze handles. Some writers have surmised that iron was much more common in the barbaric culture stage than is commonly supposed, and explain the absence of numerous iron implements in barbarian ruins by the supposition that such iron tools

had been destroyed by oxidation, while the bronze implements had remained practically unaffected, and hence are now much more numerous. However, the existence of the bronze age is proved by other testimony than that of the implements found. In the various Aryan languages, for example, the words for "bronze" are practically identical, although the nations have scattered to regions as widely separated as Hindustan, Greece, Rome, and Western Europe. The names for iron on the other hand, are different in the same languages, of nations of the same stock, showing that iron was not discovered until after the separation of the different nations had taken place.

In various other ways the existence of a bronze age preceding that of iron has been demonstrated. For example, after iron came into common use, bronze, being the older metal, was specified for many sacred uses, in connection with religious customs, just as, during the bronze age, sacrifices were required to be made with implements of stone. In the Bible we learn that the only metals allowed to be used on the construction of the tabernacle were gold, silver and bronze; and for the altar, erected by the Israelites after crossing the Jordan, the stones were not to be touched with any iron tool. This indirect evidence helps to prove the existence of a bronze age between those of stone and iron.

Iron, however, is much superior to bronze, as a material of construction in every respect except resistence to rusting. Iron is very widely disseminated over the surface of the earth, and constitutes a considerable per cent of the materials of the outer crust. Copper is a much more rare metal, and more costly in our day. Tin, zinc and lead are still more rare than copper.

Iron and steel tools are much superior to those of bronze. Iron can be welded, while bronze must be cast, and the only method of mending a broken bronze article was by recasting. Iron does not materially change its properties under repeated treatment, but bronze lost some proportion of tin after each recasting. These advantages brought about the general use of iron throughout the latter part of the barbaric age, and have led to its adoption by modern barbarians, and even by modern savage tribes, who have learned its use, not by natural culture development, but through its introduction by more highly civilized peoples.

82 **The Effect of Barbaric Culture Conditions upon Engineering.** The rate of development of engineering in the barbaric culture stage was very rapid, as compared with the savage stage.

In the first place, the giving over of the mechanical industries to hereditary crafts enabled the entire craft to acquire any new discovery which might be made by one workman. It enabled the skill of each generation and the progress made by it to be handed down to the next generation; which was, therefore, in a position to effect further progress. Under such an organization of the industrial crafts, many new materials, and principles of construction, new processes, and new products, were soon developed, and in their turn they added to the rapidity of industrial progress.

Further the organization of the industrial crafts permitted the government to exert a direct control over them and to direct their energies in any desired direction, to further the execution of comprehensive plans.

In fact, the direction by despotic governments of the united efforts of great masses of men in the carrying out of the plans, and even of the whims, of the ruler, and of the priestly class, is perhaps, the most important characteritic of engineering throughout the barbaric culture stage. Not only were great masses of men required to work to one common end, but in many cases plans were formed whose execution required more than one generation. For year after year, throughout a long period of time, great masses of men could be requisitioned for any public work. Engineering in the barbaric culture stage is, therefore, remarkable for the great magnitude of some of the constructions successfully carried out. For example, in Mexico, the pyramid of Cholula required for its construction 4½ million cubic yards of material, supposed to have been mainly sun dried brick. Some of the architectural ruins in Yucatan and Central-America must have required the continuous work of multitudes of men for more than one generation.

We read of aqueducts in Peru some four or five hundred miles in length, and of two roads each 2000 miles long. In China, we have the Grand Canal, 650 miles long, and the Great Wall, 1500 miles in length. In Egypt, according to Herodotus, an hundred thousand men labored thirty years in the erection of the Great Pyramid, which still remains the greatest single mass of masonry ever erected by man. In the valley of the Tigris-Euphrates, irrigation canals were constructed of sufficient magnitude to take the entire flow of one of these great rivers; and we read with amazement, and even doubt, of reservoirs large enough to hold the flow for days at a time.

In architecture, the columns of some of the great temples of Egypt have never since been equalled in magnitude.

83. **General Similarity of Climatic and Geological Conditions in Ancient Civilization.** There seems to be a marked similarity in the general climatic conditions under which ancient civilizations have developed. In America, the high semi-arid lands of Mexico and Peru, with their extremely equable climates, were the centers of American civilizations. The Egyptian civilization developed in the valley of the Nile in Africa, and the Chaldean and Assyrian in the valley of the Tigris-Euphrates rivers, both under climatic conditions quite similar to those of Mexico and Peru. The Chinese civilization developed first in the valley of the Yellow River, in a country separated from the rest of the world by great deserts and mountain chains. The first Indo-Aryan civilization appeared in the semi-arid valleys of the great Indian rivers, of the southern slopes of the Himalaya mountains, in regions requiring irrigation on an extensive scale.

CHAPTER VIII.

ENGINEERING IN ANCIENT MEXICO.

84. **Ancient Mexican Countries and Races.** There were two centers of culture in ancient Mexico at the time of its conquest by the Spaniards in 1520.

The more northern and more extensive had its centers in the Valley of Mexico, situated in the middle of the great interior table land. Following the route of the Spaniards as they landed on the Atlantic coast, at Vera Cruz, there comes: First, a strip of low hot country along the Atlantic coast; second, a great chain of mountains, the climate changing from tropical to temperate as these are climbed; third, a vast, elevated interior table land. The Valley of Mexico, surrounded by a rampart of mountains, occupied the center of this great table land, over which prevailed a semi-arid climate, requiring irrigation for the most successful operations of agriculture. In the Valley lay several lakes, upon one of which was located the ancient city of Mexico.

Occupying this valley and the surrounding regions were a number of tribes, or nations, of an Indian stock which is known as the Nahuan. Part of these were allied with the Aztecs in ruling the ancient Mexican Empire, which extended from the Atlantic ocean to the Pacific, and from North Latitude 15 degrees to 22 degrees. Not nearly all of the area included within this territory, however, was under the rule of the Aztecs, there being a number of hostile nations or tribes.

The climate of the Valley of Mexico was very equable. It is stated that the extremes of temperature at different times of the year are only between 52 degrees F., in January, and 65 degrees F., in July. This variation of only 13 degrees between extremes, may be compared with 25 degrees at London, which has as uniform a climate as any capital of Europe, and with 45 degrees at New York City.

The Valley of Mexico, with this equable climate, and defended from external enemies by almost impassable barriers, was a very favorable point for the development of ancient culture.

To the south and southeast of Mexico, in southern Mexico, Central America, and the isthmus of Yucatan, lay the second great center of Mexican culture. The Indian races occupying this territory are known as the Mayan.

Yucatan, which perhaps is best known in connection with the Mayan culture, has a very peculiar geological and topographical formation. It is a limestone country, very level in its topography, and almost without running streams, since the water which falls upon the surface penetrates into crevices and passages in the limestone strata. At various points great sink holes have been formed, though solution of the limestone rocks by underground water, just as in many other regions where limestone forms the surface strata. It is at the bottom of these sink holes that almost the entire water supply of the country is obtained.

Outside of Yucatan, Palenqua, in the state of Chiapis, Mexico, is the site of famous ruins of an ancient city. At Oaxaca, in Southern Mexico occur extensive remains of ancient earth work constructions. Here the ancient races are called Zapotecs. At Mitla, about thirty miles east and southeast of Oaxaca, occur some of the most celebrated masonry architectural remains.

Copan, in Honduras, is another noted center of extensive architectural ruins.

Illustrative Lantern Slide No. 224, Map of the Valley of Mexico at the time of the Spanish conquest (from Prescott).

85. **History of Ancient Mexican Races.** It has already been stated that ancient Mexico was discovered and conquered by the Spaniards in 1520. The Mexicans, of both the Mayan and the Aztec races, had systems of hieroglyphic writing, and more or less imperfect historical records. Unfortunately, these were practically destroyed by the Spaniards, and very little is known of the authentic history of the Mexican races, prior to the time of the Spanish conquest. In the case of the Aztecs more is known than in the case of the Mayans.

According to Prescott,* the Aztecs were preceded by the Toltecs, who were supposed by him to have been, perhaps, more advanced in culture than the Aztecs; and he surmised they were responsible for many of the extensive constructions whose ruins are still found in Mexico. All dates prior to the time of the Spanish conquest are very uncertain. Prescott thinks that the Toltecs might have come from the north of the valley of the Mexico at about 800 A. D., and the Aztecs from the same direction at about 1200 A. D.

The Spanish conquest practically destroyed the ancient Mexican culture, although the descendants of these ancient peoples, with their blood intermingled with that of their conquerors, still inhabit the same regions.

86. **General Culture Condition of the Ancient Mexicans.** It has already been stated, in Article 79, that the Mexicans occupied a low position among barbaric nations in point of culture condition.

Mexican culture represents simply an advance upon that of the North American Indians, and Mound Builders, and Pueblo Indians, though there are some anomalies in connection with it which can most readily be explained by assuming that Mexican civilization had been influenced by the crews of shipwrecked vessels, driven across the Atlantic and Pacific oceans, from Europe and Asia respectively.

They knew of *bronze*, but used it so seldom that Mexican bronze implements are among the most rare specimens to be found in archeological museums.

The general system of *government*, was quite advanced. The emperor was chosen from the royal family by a council of four electors. There was a regular organization of ministers and advisers. The Aztecs had a good judicial system, with courts of appeal to insure the administration of justice. There was a system of hereditary and appointive nobility. Slaves were well protected by the laws and every child was born free.

The Aztec *religion* included a moral code of a very advanced character, containing much that is similar to our moral religious codes of the present day. In contrast with this may be mentioned the extensive system of human religious sacrifices, with accompanying cannibal customers. There was an extensive priestly class.

* Conquest of America.

Mexican art was grotesque and comparatively rude. There were many temples.

The Mexican government maintained an extensive *army,* with a regular systematic organization, under officers of different rank. It is stated that 200,000 men could be put into the field.

Illustrative Lantern Slides. No. 271. Small section of paneled design from lintel in Catholic Establishment group of Mitla. (From Holmes.) No. 229. Altar piece in stucco, from Palenque. (From Holmes, after Waldeck.) No. 247. Sanctuary tablet, with sculptures in low relief. (From Holmes.) No. 246. Onyx tablet from interior temple wall. (From Holmes.) No. 226. Sculptured stone idol, at Copan, Honduras, 13 feet high. (From Stevens.) All of the above illustrating ancient Mexican art.

Social conditions among the Aztecs were comparatively high. The children of the upper classes were given the advantages of education at regular schools, conducted at temples by the priests.

87. **Ancient Mexican Science, Mathematics, etc.** It has already been stated that the Mexicans had a system of *hieroglyphic writing.* In the development of hieroglyphics, three stages are recognized. In the first stage, we have picture writing, of which the American Indians have the beginning type in our own day. By more or less rude representations of actual objects and happenings, ideas are conveyed to other than the writers. In the second stage, the representations are conventionalized into hieroglyphics proper, with very slight resemblance to actual objects, and each character is made to represent a word or an idea rather than an actual object or occurrence. In the third stage, the hieroglyphics represent sounds, or syllables, rather than words.

The Mexicans had developed all three stages, but at so recent a period that the meaning of the different hieroglyphics varied under different conditions, and hence only carefully trained natives could decipher Mexican writings. Unfortunately the art of deciphering them was lost at the time of the conquest, and has never been recovered.

The ancient Mexicans wrote their *books* upon sheets of paper, made from the Maguey plant. This paper was prepared in long strips, which were folded in zig-zag fashion. The addition of a cover on each side made a rectangular book, quite similar to our modern books, which may be contrasted with the rolls upon which the ancient Greeks and Romans did their writing in the first civilized culture stage. These Mexican books were more convenient than such rolls.

Illustrative Lantern Slides. No. 240. Inscribed stela, or column. (From Holmes.) No. 213. Mayan hieroglyphics. (Baldwin's Ancient America.) Both the above illustrate the character of the Ancient Mexican hieroglyphics.

The Mexicans had developed a system of *Mathematics,* with multiples of twenty as the basis of their numbers. They had separate names for the numbers from one to five. Six was five-one; seven, five-two, etc. There were also separate words for twenty, four hundred, and eight thousand. In writing numbers, a point equalled one; a flag, twenty; a feather, four hundred, and a purse, eight thousand. By coloring fractional portions of these symbols they could indicate three-fourths, one-half, one-fourth, etc., of each number. Thus, three-fourths of a purse, one-fourth of a feather, one-half of a flag, and two dots, would indicate the number six thousand, one hundred twelve. It is stated that this system of writing numbers was more simple than that in use by the ancient Romans. In their commercial transactions, the Mexicans kept accounts by systems of tallies, as was the case with the more advanced savage tribes.

The Mexicans had a highly developed *calendar system,* which shows that they must have kept astronomical records for a long period of years. In general, such records began to be kept by savage nations, in their later culture stages, and especially, when they developed religious systems in which priests devoted their full time to priestly duties. A continued observation of different phases of the moon gave the idea of the lunar month at a comparatively early

stage of culture. Similarly, observations of shadows cast by the sun shining upon a fixed object, together with observations of the positions of the stars, in the heavens at different seasons of the year, gave, after a time, a measure of the length of the year. Barbaric peoples, and even some savage tribes, have pillars and other devices for conducting such astronomical observations.

Similarly, observations of eclipses, continued and recorded for long periods of time, accumulated after a time data from which eclipses could be predicted, although the prediction of eclipses belongs to a more advanced stage of culture than that of the Mexicans. However, Prescott states that the true cause of eclipses of the moon, namely that of the shadow of the earth cast upon it by the sun, was shown on their picture writings.

They had a more accurate calendar system than that used by more advanced nations, even the Romans and Greeks. The Mexican week was five days long. They divided the year into eighteen months, of twenty days each, with five intercalary days at the end. Four years constituted a quadrennial *period.* After an *epoch,* of thirteen such periods, of fifty-two years, they added twelve and a half surplus days, just as we add one each leap year. Hence, 365.24 days constituted a Mexican year, which was nearer to the correct length than the Roman year.

The ancient Mexican calendar was recorded in one instance upon a large stone, some eleven feet in diameter, the zodiacal signs being cut into the hard porphyry. This famous "calendar stone" is still in existence in the City of Mexico.

The Aztecs had, of course, little knowledge of science, as we know it at the present time. Hittell claims that they had a system of balances and weights. Most authorities, however, deny their use of scales.

In connection with Mexican science, it is a noteworthy fact that at the time of the Spanish conquest they had great botanical and zoological gardens, the largest in the world at that time. It is stated that at the City of Mexico, 600 men were required to care for the menagerie alone.

88. **Ancient Mexican Commerce and Manufactures.**

Commerce. Commerce was carried on, among the ancient Mexicans, by a series of weekly fairs, held at the Mexican cities, at intervals of five days. The merchants transported packages of such size that they could be carried by slave porters, on land, or in canoes, on water. These merchants' caravans penetrated into the surrounding countries, and carried on active commerce with their peoples.

Agriculture. In agriculture, the ancient Mexicans were very expert, although they used rude tools. The ground was cultivated by means of wooden digging sticks, or spades, with a cross-piece near the bottom for applying pressure with the foot in forcing the spade into the ground. The land was owned largely by the emperor, the nobles and the church. It was laid out in regular fields, which were farmed by the freemen.

Crafts. The mechanical industries among the ancient Mexicans were carried on by separate crafts, the number of which may be judged from the following enumeration made by Hittell:* "Miners, smelters, smiths, burnishers, engravers in metal, gilders, quarrymen, stone masons, stone polishers, cutters of gems, makers of mosaics, sculptors, enamelers, jewelers, knife makers, lime burners, charcoal burners, brick makers, potters, plasterers, boat builders, carpenters, dressers of skins, weavers, cacoo grinders, bakers, brewers, cigar makers, barbers, salt boilers, paper makers, India rubber workers, and manufacturers of medicines and pigments."

Manufactures. The extent of manufactures can be judged by the list of crafts, given above.

While India rubber was known, its use was not prominent.

The ancient Mexicans were especially expert in the manufacture of cotton cloth. They spun the cotton into threads so fine that the fabric woven from it was compared by the Spaniards to silk.

*Mankind in Ancient Times. Vol. II. page 20.

Mexican feather garments were still more remarkable than their cotton cloths, and attracted much attention in Europe when sent there at the time of the Spanish conquest.

The maguey plant was very important in ancient Mexican economy. They secured a food from its roasted roots; they manufactured an intoxicating beverage from its sap; they made cloth from its fiber; and paper from its leaves, which were also used for the thatching of the houses.

89. **Ancient Mexican Tools and Mechanical Devices.** The metal workers of the ancient Mexicans were able to cast gold and silver in such a way that the two metals would unite at their edges without mixing. The secret of this art has been lost. For example, they made artificial fish, in which the alternating scales were gold and silver.

As has already been stated, there has been a dispute as to whether or not the ancient Mexicans were acquainted with the use of scales.

While they had begun to use bronze, yet stone was their principal material for cutting implements, and they made use of wood, bone, and shell, in a manner already indicated in the description of savage culture. With these implements, they were able to execute skillful work in many lines. Some examples of their skill in stone carving are shown in the illustrative lantern slides, in which also are shown a broken bone drill, which was found where it had actually been used in drilling a piece of hard stone.

The cutting implements of the ancient Mexicans were largely made of obsidian, a dark transparent mineral, exceedingly hard, found in abundance in the hills, which could readily be flaked off into knives of considerable length. Obsidian knives were so sharp as to be used by the barbers, but the edges of implements were soon blunted.

The Mexican sword, the maquahuitl, consisted of blades of stone set in a wooden handle.

In view of the high degree of skill in stone cutting which was attained by the ancient Mexicans, it seems remarkable that the only implements which they used for this work consisted of rude stone picks, with wooden handles.

Illustrative Lantern Slides. No. 267. Four views of a sculptured stone yoke, showing skill in carving hard stone with rude implements. No. 272. Cross section of a perforated tablet, showing broken bone drill which has been used in preparing the tablet. (Both the above from Holmes' "Visit to Buried Cities of Ancient Mexico." Vol. II.) No. 85. Zuni jeweler drilling turquois, showing method used by ancient artisans to drill hard stones.

90. **Mining and Metallurgy in Ancient Mexico.** The ancient Mexicans mined gold, silver, copper and tin. They also used cinnabar for pigment, and Hittel questions whether they might not also have known how to sublimate it for quicksilver, which would explain some of their metallurgical processes which are not now understood. There is, however, no authentic record of their use of quicksilver. In their mining operations, they knew how to sink shafts, and run tunnels. They washed gold from alluvial deposits.

Prescott states that they obtained silver, lead and tin from the mines of Tasco, and copper from the mines of Zacatallan.

In their metallurgical operations, they used furnaces for smelting the ores of copper, tin, lead and silver, and in casting metals, with bellows for forced draft. They made blow pipes, crucibles and moulds. From the precious metals they made many articles of use and ornament, such as vases, plates, mirrors, bells, ear-rings, bracelets, armlets, anklets, cups, bowls, dishes, pots, kettles with fixed and movable handles.

Mention has already been made of the dispute over the question as to whether or not they had scales. Hittell says they did, and that they determined the proportion of alloys by the principle of specific gravity. They had no solder, but cast gold and silver in such a way as to unite them along a sharp line. As already stated, this is an art which is no longer known.

91. **Ceramics in Ancient Mexico.** The ancient Mexicans were very skillful in the manufacture of pottery. Holmes stated that in a district at the city

of Mexico extending two or three miles to the northeast from the Mexican Railway station, excavations for brick making have exposed sections of soil eighteen or twenty feet deep, in which the entire deposit seems filled with ruins of dwellings, and that at least one-fourth of the mass is composed of broken pottery. The prevailing ware is extremely rude, but mixed in with it is a better product, with polished and painted surfaces, and near the top are countless numbers of broken Aztec vases. It is surmised that the ancient potters might have had their markets located in this vicinity. The deposits have not been thoroughly studied.

The Mexican potters did not invent or use the potter's wheel.

The manufacture of brick was also a very important department of the ceramic art of the ancient Mexicans. The majority of the dwellings of the lower classes were made of adobe, or sun dried brick, often placed on stone foundations. The Mexicans also made burned brick.

Floors were sometimes paved with tiles.

In many cases the mortar for their masonry was made of earth mixed with pebbles and limestone fragments, but lime was extensively burned to make true lime mortar.

They also burned gypsum to use for stucco, which was employed in large quantities in finishing the surfaces of their dwellings, and of masonry structures in general.

92. **Ancient Mexican Masonry.** While the houses of the common people, as has already been stated, were generally made of adobe, or sun dried brick, the better class of dwellings were frequently made of stone masonry, especially in those localities where easily worked stone occurred in abundance.

The ancient Mexicans also used masonry very extensively for covering the inclined surfaces and terraces of their great pyramids, and for the building of palaces, temples, and other monumental structures. Hittell states that they used porphyry, basalt, marble and granite extensively in their architectural constructions, and onyx and brick occasionally. Prescott states that the houses and other masonry structures in ancient Mexico were made of amygdaloid.

According to Holmes, the masonry in Yucatan was made of blocks of a limestone which could readily be broken into regular shapes, and which could be easily worked. At Palenque, also, the material was limestone, somewhat harder than that at Yucatan. At Mitla, in southern Mexico, the material was trachyte, which breaks down in great blocks, of regular shape, along exposed cliffs, and which is very tractable and easily worked, while at the same time tough and durable

Both the Nahuan and the Mayan races showed skill in quarrying, transporting and shaping stone for their masonry constructions. The individual blocks were, in many cases, of large size, and great weight; yet these great masses of stone were transported in large quantities for many miles at Mitla, and doubtless at other cities. At Mitla, Holmes discovered the ancient quarries. The main quarries are located at an elevation about 1000 feet higher than the city, and at a distance of about five or six miles. The individual blocks of stone weighed many tons. Two miles east of Mitla he found a partially hewn block of trachyte, which was originally twenty-five feet long by five or six feet square, and which therefore must have weighed about sixty tons.

The ancient calendar stone at the city of Mexico was transported a distance of, perhaps, thirty miles across rough country, and is stated by Prescott, to have weighed fifty tons. (Hittell says twenty-four tons.)

In all cases of transporting great weights, the work was done by large numbers of men working in unison, and dragging the stone by human strength. Doubtless levers and rollers and sledges were used, very much as we see illustrated on the monuments of ancient Egypt and Chaldea. There is a legend to the effect that ten thousand men were used in transporting the "calendar stone" of ancient Mexico.

Considering the degree of skill in stone cutting shown in the ornamentation of the masonry of still existing architectural ruins, it seems hardly

credible that the work could have been executed entirely with rude picks and other implements of stone, yet this seems to be demonstrated. In fact, Holmes found the ancient stone cutters' tools, in the immediate vicinity of the quarries where the stone was secured and wrough. These tools are simply rude picks and hammers of stone, views of some of which are given in the illustrative lantern slides. In use they were, of course, provided with handles of wood.

The government was despotic, and the work of great numbers of men could be commanded for year after year, without pay, for any public service.

In their quarrying, the individual stones were separated from the strata by vertical cuts about a foot wide, surrounding them on all sides, these cuts being made by pounding with the stone picks already referred to. After the stone was separated on all sides it was undercut, and then detached by wedging.

Illustrative Lantern Slides. Nos. 233, 275 and 228. Showing method of cutting out blocks of trachyte in a quarry. (From Holmes, drawn from actual observation.) No. 244. Stone Picks. No. 266. Stone Hammers and picks. Found by Holmes in the vicinity of the Mitla quarries. These are good specimens of the tools which were used in quarrying and shaping stones by the ancient Mexicans, and with which finely executed ornamental carvings were produced. In actual use they were of course provided with wooden handles. No. 289. Court and east chamber of the Quadrangle of the Greques, ruins of Mitla. No. 258. Part of the sculptured facade, "Governor's Palace," Uxmal, Yucatan, 10 feet high by 725 feet long, containing twenty thousand elaborately sculptured pieces of stone. These slides are all taken from Holmes, and illustrate the nature of the stone cutting done with the rude tools above.

While the ancient Mexicans did use and carve great masses of stone, as already indicated, in their masonry constructions, yet it must not be supposed that the bulk of their masonry structures was made of such great stone blocks. In fact their knowledge of the proper principles of masonry constructions was limited, and they violated many of the elementary principles which are followed today by all engineers and architects. They did not know the principle of breaking joints, for example, nor that of properly bonding the masonry across the wall.

Their walls were very thick, in some cases occupying more than half the area of the building. In general, they consisted of a facing and a backing of stone blocks, and a connecting hearting, which was made of earth, mingled with limestone fragments and pebbles.

They also used limestone mortar extensively, both in laying up the facing and backing, and in the making of the hearting. Analyses have been made of this mortar, which show that it was probably made of burned lime, rather than pulverized limestone.

Hittell states that the ancient Mexicans were acquainted with the principle of the true arch, and that they used it in ovens, and similar small constructions, but not in architecture. The author of these lectures has not seen any other evidence than this of the use by the ancient Mexicans of the principle of the true arch. In their architectural constructions they invariably used the horizontal coursed arch, which has been independently developed by many nations, and was even known to many savage trikes, such as the Esquimos.

In constructing the horizontal coursed arch, the space to be spanned is arched over by successively projecting courses of horizontal masonry, which finally meet at the center. The principle is that of the cantilever, rather than that of the true arch. In Mexican masonry structures the space arched over was narrow, being only a few feet wide. To prevent the over balancing of the walls before the projections met at the top, wooden poles, or in some cases, stone slabs were used during construction, and their remains are often encountered still.

While the Mexicans generally used the horizontal coursed arch to roof over enclosed spaces, yet in ordinary dwellings they used beams and poles covered with packed earth, and at Mitla the same principle was followed in covering

over their monumental structures. In some cases, however, slabs of stone were substituted for wooden beams or poles. In a few cases, the Mexicans seem to have used columns to support such roofs.

Illustrative Lantern Slides. No. 239. (From Holmes.) Shows cross-section of Mayan arches and illustrates the character of their masonry, as already described above. No. 237. (From Holmes.) A cross-section of a Mayan masonry structure, with an interior division wall, showing wooden lintels over openings, exterior walls ornamented by cornices, and an ornamental crest over the center of the roof of the structure. It further illustrates the general character of the Mayan masonry wall, with facing, backing, and hearting, and also the nature of the sub-structure, which was usually a pyramid of earth and stone, with masonry facing. In slide No. 237, the foundation walls are shown extending down through this sub-scructure. No. 254. (From Holmes.) A view prepared from a photograph showing the interior of a characteristic Mayan vaulted chamber. Notice the horizontal coursed arch, and the openings for the wooden poles used during construction; also the narrow width of the chamber, the absence of all window openings, and the stone lintels over the wall openings. No. 241. (From Holmes.) Transverse generalized section of characteristic Palenque building. Notice the wooden lintels over the openings, the provision for attaching hangings at wall openings, the sloping external surfaces of the horizontal coursed arch, and the roof crests. Also the truncated pyramidal sub-structure. No. 269. (From Holmes.) Showing flat roof construction at Mitla. Horizontal wooden or stone beams span the openings, on the top of which are placed poles, earth and stone. No. 203. (From Holmes.) Showing the use of the column at Mitla, to span a larger opening than is possible with a single span.

93. **Ancient Mexican Architecture.** Some discussion of the dwellings of the ancient Mexicans has already been given. With few exceptions, they were one story in height; but a few of the better buildings added one or more stories to the first. The dwellings of the common people were made, in some instances, of wood, but very generally of adobe, or sun dried brick. The dwellings of the nobles and richer people were often of stone. The roofs in general were flat, as already described. They did not use doors or windows. The openings were stopped with hangings. In some instances, the floors were covered by tiles, and in some other cases a sort of concrete floor, with limestone mortar, was used. In the humbler dwellings, the floors were simply beaten earth.

We must look to the religious and monumental structures of the ancient Mexicans for their greatest achievements in architecture.

Almost without exception in their architectural construction, the real structure was elevated on a truncated pyramidal sub-structure, which in some cases formed the most important part of the entire construction. In the vicinity of the city of Mexico these sub-structures generally consisted of great masses of mingled earth and stone. The exteriors, however, were cased with stone masonry, and a number of terraces were provided along the sides.

In the case of the ancient Mexican pyramids, the successive terraces were so arranged that to reach the top, the religious procession passed around the entire structure on each terrace. The real temples, on the top, were very small structures, generally of masonry. In Yucatan, and at Palenque and Mitla, the masonry superstructures were of very much greater importance. They were erected with great skill, on the principles of masonry construction already described. Important sites at which extensive remains of monumental masonry structures are still found are Uxmal and Chichenitza, in northern Yucatan, and Palenque to the west of Uxmal, along the foothills of the eastern coast of the mainland of Mexico. Copan, in Honduras, is another site of ancient ruins. At the city of Caxaca, about thirty miles north of Mitla, there are the remains of very extensive earth constructions by ancient Mexicans.

Illustrative Lantern Slides. No. 281. Panoramic view of pyramids and other remains of prehistoric constructions, at Teotihuacan, about twenty-five miles northeast of the city of Mexico (Holmes). No. 262. Teotihuacan, from the Pyramids of the Moon, showing the Pyramid of the Sun (Holmes). No. 253. Foundations of house, exposed by Charnet's excavations, at Teotihuacan (Holmes). The lantern slides named above illustrate prehistoric remains at one of the centers of population near the City of Mexico. The principal pyramids are now called the Pyramid of the Sun, and the Pyramid of the Moon. The former is approximately 700 feet square at the base, by 180 feet high, the summit being about 100 feet square. The Pyramid of the Moon has a base about 450 feet north and south, by 500 feet east and west, the summit being about 50 by 60 feet. No. 227. Bottom of an ancient reservoir, or water supply, in Yucatan. No. 212. Subterranean reservoir, in Yucatan, (both from Baldwin's Ancient America), illustrating the difficulties of obtaining water supply in the lime stone region of Yucatan, as already described, and the methods employed by the ancient Mexicans to overcome these difficulties. No. 286. Panoramic view of extensive earth constructions, on slope of mountain ridges in Oaxaca. The entire outline of the mountain ridges has been changed by these artificial constructions of ancient times. (From Holmes.) No. 24. Small ruined temple on Mugeres Island, off the coast of Yucatan. (From Holmes.) No. 265. Pyramid Temple at El Meco, mainland of Yucatan. (From Holmes.) No. 263. Showing development of the ground plan of Mayan temples, Yucatan, beginning with one room and gradually developing into several, with a holy chamber in the interior. (From Holmes.) No. 207. Circular edifice at Mayapan. (From Baldwin's Ancient America.) No. 211. Ruined arch at Kabah, showing very fine example of horizontal coursed arch. (From Boldwin's Ancient America.) No. 260. Showing cord holders for hangings, at wall openings. (From Holmes.) No. 261. Showing construction of single doorway, and No. 268, showing construction of triple doorway (both from Holmes), illustrating the most highly developed details of temples in Yucatan. Nos. 243 and 250. A feathered serpent column, at Chichen-Ltza, northeastern Yucatan, (from Holmes), showing the nearest approach to a regular order of architecture yet discovered in connection with ancient Mexican architecture. The column represents a rattle snake. Notice the wooden lintels and cornice over the top. No. 287. Middle portion of the "House of the Pigeons." (Holmes.) Notice the peculiar raised roof crest ornamentation. No. 285. East Facade of one of the structures at Chichen-Itza, northeastern Yucatan. (From Holmes.) No. 235. Showing square columns as employed in one of the structures, known as The Temple of the Tables, at Chichen-Itza, Yucatan. (From Holmes.) The use of columns of any description was exceedingly rare in ancient Mexican architecture. In all ancient Mexican architecture a very extensive use was made of stucco for smoothing up exposed masonry surfaces. The exposed surfaces were then painted in vivid colors. One of the designs at Mitla is illustrated in lantern slide No. 271, described above. These ancient decorations were renewed time after time, and in some cases many coats of paint were found. No. 282. Panoramic view of Palenque, Mexico, showing architectural remains. The structures appear as they would if the vegetation were removed. In the valley shown in the picture, a long and very large storm sewer was constructed by the prehistoric engineers, to carry away the storm water and protect the foundations of the structures shown in the picture. The exact length is not known, but it was at least many hundred feet. No. 219. Remains of Teocalli or Temple at Palenque (from Encyclopedia Britannica), giving a better idea of actual appearance of the ruins, overgrown by luxuriant forest. No. 256. Ground plan of "Palace," at Palenque, showing the complex development of the ground plans of structures. (From Holmes.) This slide also shows the approximate location of the storm sewer already referred to. No. 236. Showing ground plans of similar structures at Palenque, showing gradual development of complexity. A representation of the god, like those already illustrated in connection with Article 86, was placed in the holiest chamber. (From Holmes.) No. 225. Front cor-

ridor of Palace at Palenque. (From Stevens.) No. 230. Temple of the Sun, Palenque. (From Holmes.) No. 231. View in northwest court of Palace, showing decorated piers and tower. Towers were very unusual in Mexican architecture. (From Holmes.) No. 259. Panoramic view of the ruins and modern village at Mitla, State of Ozxaca, Mexico. (From Holmes.) No. 290. Cut from photographic view of one of the masonry structures at Mitla. (From Holmes.) No. 271. Small sections from painted design, from one of the structures at Mitla. (From Holmes.) No. 270 Interior of the Hall of Six Columns at Mitla, showing the use of circular stone columns to span a comparatively wide opening for the flat roof construction. The use of columns was very unusual. (From Holmes.) No. 274. Mitlan women, spinning and weaving, showing the continued use of methods of spinning and weaving developed in the more advanced savage culture stage already illustrated by a similar view of a Zuni Indian at work. No. 201. The Great wall, at Copan, British Honduras. (From Baldwin's Ancient America.) This wall is 60 to 90 feet high and some 625 feet long. Above it were the remains of many masonry structures. Copan, however, is especially famous as being the site on which were discovered many sculptured stone idols, one of which has already been illustrated in connection with Article 86.

94. **Ancient Mexican Cities.** It appears that the population of the Valley of the Mexico was denser when it was first discovered by the Spaniards than now. Hittell states that the ancient cities of Mexico and Tezcuco had 300,000 inhabitants each at the time of the conquest, and that there were many cities in the Valley with a population of several thousand each. Prescott states that the streets of ancient Mexico were laid out at right angles to each other, and that the principal streets radiated out from the great Teocalli temple as a center. He states that the streets were mostly narrow, but that the principal north and south street was wide and straight, extending through the entire city. He also states that the main streets were paved with a hard "cement." Hittell states that some of the streets were paved with stone. Neither the ancient Mexicans nor any other ancient people knew anything about true cement.

The principal streets were intersected by numerous canals, as the city of ancient Mexico was built at a very slight elevation above the lake, and over these canals were many bridges, usually draw bridges. Prescott states that there was a regular street cleaning system, in which one thousand persons were employed daily to sweep and water the streets. One of the Spaniards present at the time of the conquest wrote that the streets were kept so clean that a man could walk through the city "with as little danger of soiling his feet as his hands."

In the city of ancient Mexico, there were very extensive palaces for the monarch, and the dwellings of the nobles were also large and costly. These and the temples formed the principal architectural constructions. This was true both of Mexico, and also of Tezcuco, which was especially noted for the palace of its monarch.

95. **Sanitary Engineering Among the Ancient Mexicans.** At least the principal Mexican cities were provided with regular water supplies, brought in by aqueducts from a considerable distance. Hittell states that there was a double aqueduct for the city of Mexico, the source of supply being at Chapultepec. He further states that each of the channels was six feet square, but this seems to be much larger than the actual fact. Prescott states that the water supply was brought by two pipes, each "the size of a man's body." He states that the water was carried to the houses by hand from the points where this aquaduct crossed the canals, using canoes. He states that there was a large reservoir at Chapultepec. Hittell states that the city of Tezcuco was supplied with water from a reservoir.

Ewbanks' Hydraulics, 1842, quoting from Herara, states that when the Spaniards reached Tezcuco the streets were very regular, and that fresh water was brought in pipes from the mountains to every home. Undoubtedly, this

is an exaggeration, but it is certain that the fountains and baths of the palace of the monarch at Tezuco were very famous at the time of the conquest. Ewbanks also states that the Tlascalans had baths and fountains. It seems certain that in the palaces of the monarchs and of the great nobles, provision was commonly made for a regular water supply for baths and fountains.

In connection with sanitary engineering among the ancient Mexicans, we must not forget the storm sewer at Palenque, which has already been mentioned in connection with the illustrative lantern slides in Article 893.

Illustrative Lantern Slides. No. 276. Section of waterway arch, Palenque, height 10 feet. This storm sewer was several hundred feet in length, but its point of beginning is unknown. As shown by the lantern slide, it was constructed on the principle of the horizontal arch.

96. **Irrigation and Hydraulic Engineering in Ancient Mexico.** By a number of references in Prescott and other authorities, it is evident that irrigation was practiced on an extensive scale in ancient Mexico, and throughout the country inhabited by the Aztecs, but details are lacking.

97. **Navigation in Ancient Mexico.** The ancient Mexicans had no shipping. They used canoes, however, extensively in connection with transportation, as already mentioned in Article 88. All descriptions of the Spanish conquest represent the lakes in the Valley of Mexico as swarming with craft of this type. Hittell names boat-builders as belonging to a separate craft.

98. **Land Transportation in Ancient Mexico.**

Roads. Land transportation in ancient Mexico was by human carrier, as already stated. They had no beasts of burden, nor vehicles. They did little along the line of road construction, but had regular trails or paths leading to all parts of the empire, with station buildings at intervals of about six miles for the accommodation of couriers. These couriers carried news and packages, and ran at top speed, each one having only a short distance to travel. In this way sea fish were carried fresh from the ocean to the table of the monarch. Hittell says that the six mile stage was made in a little more than half an hour.

Dikes. While the Aztecs did little in the matter of road construction, yet in the Valley of Mexico they carried out important engineering work in the construction of dikes, by which land communication across the lakes in the valley was assured. The largest of these dikes was seven miles long by sixty feet wide. It was covered for most of the length by stones laid in mortar, and was protected at the side by piling.

Bridges. The Aztecs also built numerous small bridges. Most of these were doubtless of wood, but in several instances they were constructed of stone.

Illustrative Lantern Slide. No. 264. Bridge arch. (From Holmes.) This illustrates a masonry bridge crossing a small stream, a short distance below Palenque, in southern Mexico.

CHAPTER IX

ENGINEERING IN ANCIENT PERU.

99. **Ancient Peruvian Country and Races.** The country of ancient Peru extended along the coast of South America approximately from latitude 2 degrees north to 37 degrees south. These are the limits given by Prescott.* Hittell** gives the length of the Peruvian empire as approximately 2000 miles. It was continually increasing, and the limits given by Prescott are those attained just prior to the Spanish conquest. The width of the Empire averaged perhaps 200 miles, the eastern boundary being the foot of the eastern flank of the Andes mountains. About nine-tenths of the empire was within the torrid zone, but owing to the large proportion of mountain territory the climatic conditions ranged from torrid to arctic.

* Conquest of Mexico.
** Mankind in Ancient times.

In general the coast regions were comparatively arid, requiring irrigation. Passing into the interior, the western slopes of the Andes are soon encountered, and these mountains rise to regions of perpetual snow. From these mountain ranges water supply was secured for irrigation purposes.

The Peruvian capital was Cuzco, on the eastern slope of the Andes, located on a tributary of the Amazon River. The climate here was very equable. This was also true of the climate of Quito, the second city of the empire, 900 miles north, located in 0 degrees 15 minutes, south latitude. Hittell states that the variation of average temperature in the extreme months of the year at Quito was only from 50 degrees in January to 59 degrees in July.

In considering the topography and climate of ancient Peru, one cannot but be struck by its resemblances to those of other centers of ancient civilization, as already described in Article 83. We have the same arid climate, requiring irrigation on a large scale, for which an organized government was necessary. We also have an equable temperature, favorable to the prosperous development of culture. Further, the interior forests of South America on the east and the ocean on the west, constituted almost impassable barriers against hostile invasion.

The ruling Peruvian race was that of the Incas, the members of which were supposed to have descended from the original founder of the Peruvian Empire The Inca race constituted the hereditary nobility of the Empire. They were simply a highly developed American Red Indian race. The common people were made up of various conquered tribes, all directly incorporated into the Peruvian Empire. At the time of the Spanish conquest there was no division into friendly and hostile nations, as in the case of the ancient Mexicans.

Illustrative Lantern Slide. No. 307. Map of Peru at the time of the Spanish Conquest. (From Prescott's Conquest of Mexico.) This map shows only the portion of the empire north of 20 degrees south latitude.

100. **History of Ancient Peru.** The ancient Peruvians did not have any system of written records and while they did manage to keep imperfect records by means of their quipus, or knotted cords, to be described later, yet in this particular they were far behind the ancient Mexicans. Little is known, therefore, of their history prior to the Spanish conquest, except as records of their legends were made by the Spaniards at the time. According to such legends, the empire had been established about 500 years previous to 1533, the date of the conquest, but it seems probable that the Inca race really secured control at about 1250 A. D.

Certain architectural remains at Lake Titicaca, and elsewhere, are supposed to have been of still earlier date, and indicate that there was a long period of preceding development in this region. Lake Titicaca seems to have been the ancient center of Peruvian culture.

The Peruvian Incas continually extended the limits of their empire by conquest, so that it was growing throughout the entire period of their history.

101. **General Culture Conditions of the Ancient Peruvians.**

Military. There was a regular military organization, and all male subjects of suitable age were expected to do military service. They were given regular drills and were systematically organized. It is stated that there were 200,000 men in the army.

Polity. The Peruvians had a most extraordinary system of polity, in which the government was everything. At the head was the Inca himself, who was supposed to be divine, so that he centered in himself both the government and religion. The members of the Inca race were all supposed to be directly descended from the original Inca, and constituted an hereditary nobility, scattered throughout the empire, and in direct touch with the Inca himself. The people were organized in squads of ten families, each under a regular officer, ten of these groups under a higher officer, etc., so that the government had absolute control over all its subjects.

The government prescribed by law the exact occupations of all its subjects, provided against poverty and famine, and even interfered in their domestic

relations. There is no other known example of such absolute governmental control of all private and public affairs as seems to have existed in ancient Peru.

Religion was Polytheistic, and the gods of all conquered tribes were adopted among these of the Empire. The chief object of worship was the sun. There was little human sacrifice. There was a numerous priestly body. All of the priests were nobles. There were numerous temples. Morality had a very prominent place in Peruvian religion. Common salutations were such as "Revere the truth," "Be industrious."

Social conditions were greatly affected by the absolute governmental control already spoken of. Marriage, for example, was compulsory, at fixed ages. The country was divided into communes, and the tillable soil was separated into three parts, devoted respectively to the church, the state and the people. The people, of course, tilled all three, but no person could acquire title to any tract of land. The government collected all surplus products, and put them into warehouses, for its own use, and to provide against famine. It prescribed the exact occupation of every person.

Art. The art of the ancient Peruvian was more crude than that of the Mexican.

Education. There was a provision for education somewhat similar to that of the Mexicans. All the Inca males were sent to schools in the temples.

Illustrative Lantern Slide. No. 305. Head of Tiaguanaco. (From Lufkin's History of Art.) This represents the head of a god, being 3 feet 6 inches in height, and 2 feet 7 inches in width. The whole statue was about 18 feet high.

102. **Ancient Peruvian Science, Mathematics, etc.** It has already been stated that the Peruvians had no system of writing. They kept records, however, by means of *quipus*, or cords; which, by means of different knots, colors, and modes of combination, served to keep record of population, fields, products, llamas, etc., in every commune, department, and province. By this same means they also kept records of laws, history, and religious legends and ceremonies. The knots, colors and combinations served as aids to the memory and stood for different objects and ideas; just as do hieroglyphic signs, and letters of the alphabet, in system of written records.

The Quipus, of course, furnished a system which was very much inferior to writing, but more could be and was accomplished with it than would seem possible to us of the present day.

The ancient Peruvians were little advanced along lines of astronomy and mathematics. Their calendar year was 365 days long, divided into twelve months, with some surplus intercalary days. They had vertical columns to enable them to ascertain the solstices and equinoxes, by observations of the shadows cast by the sun.

103. **Ancient Peruvian Commerce and Industries.**

Commerce. The ancient Peruvian commerce was, of course, greatly limited by the absolute governmental control of all industries and manufactures. Surplus products, as already stated, were collected into warehouses and distributed to the people as necessity indicated. All portions needed in other districts were transported thither under governmental control. There must have been, however, considerable commerce with surrounding peoples. In Prescott's "Conquest of Mexico," he states that one of the first instances of contact between Spaniards and Peruvians was an encounter at sea between a Spanish ship and a Peruvian trading craft, which was pursuing a trading voyage along the coast.

Agriculture. The Peruvians were especially skilled in agriculture. They conducted irrigation on a very extensive scale, as will be described further on. They cultivated the soil by means of sharp sticks pressed into the ground and dragged along by eight or ten men. They also had hoes and spades of wood or bronze. They used fertilizers, and among the crops they cultivated were maize, plantains, cotton, tobacco, agave, and bamboo. Their domestic

animals included the dog, goose, an animal similar to the guinea pig, and the llama. In the domestication of the latter they were much in advance of the ancient Mexicans.

Crafts. The different mechanical industries were carried on by crafts, as generally in the barbaric culture stage. The Peruvians were especially skilled in the weaving and dying of fine cloths. For this purpose they had not only maguey fiber and cotton, but also the fleece of the llama, so that they were able to make woolen cloth. They had much skill in jewelry, pottery, metal working, etc. They used scales in weighing metals and other substances.

Manufactures. The nature of the manufactures of the ancient Peruvians has already been indicated in the discussion of crafts given above. The manufactures included cloth, gold, silver, copper and bronze articles, and many other articles similar to those enumerated in connection with ancient Mexico.

Porphyry, Granite, Marble, and Jasper were made into cups, bowls, vases, etc. Emerald and turquois were cut and polished by their jewellers.

Illustrative Lantern Slides. No. 309. Articles of pottery. (From Baldwin's Ancient America.) This gives some idea of the character of ornamentation of the articles. No. 308. A gold and a silver vase, showing the nature of ancient Peruvian work. (From Baldwin's Ancient America.) No. 332. Pre-Inca pottery, showing work of a race preceding the Incas. No. 316. A native weaver. (The above two from Wright's Peru.)

104. **Ancient Peruvian Tools and Mechanical Devices.** Like the ancient Mexicans, the ancient Peruvians were familiar with bronze, but had not come to use it very extensively. Hittell states that they used 2 to 10 per cent of tin in their bronze alloys of copper; also, that they hardened copper with silica. Their main material for cutting implements, however, was stone, and they made extensive use of bone and woods, as did the ancient Mexicans.

105. **Ancient Peruvian Mining and Metallurgy.** The ancient Peruvians, according to Hittell, mined and smelted gold, silver, copper and tin, extensively. He also states that they used cinnabar as a pigment, and that they sublimated it for its mercury. Gold was washed from alluvial deposits, and silver smelted from the vein stone. According to Prescott, they did not sink shafts but they dug into the side of the mountains.

In their metallurgical operations they smelted the various ores by furnaces, built on elevated and exposed places to get a good draft. The same plan has been followed by other nations, down to within a comparatively recent time. Hittell states that they used furnaces of patterns still employed in Peru and Bolivia, and that they also knew the value of various minerals as fluxes to aid in the fusion of ores. Their metal workers manufactured hollow ware, figures and tools, by forging and by casting. In the gardens surrounding Peruvian temples the Spaniards found plants and figures of animals made of gold and silver. Hittell states that their patterns for casting were made of wax, and that the molds were made of clay. Besides bronze alloys of copper and tin, they also alloyed copper with gold and silver.

106. **Ancient Peruvian Ceramics.** The ancient Peruvians were skilled in the manufacture of articles of pottery.

There is much dispute as to the character of the mortar which they made and used in masonry. Squier, who has made a careful personal study of their masonry, concluded that they did not use any mortar, but simply relied upon accurate fitting of the different pieces of stone. Other authorities, on the other hand, seem unanimous in the idea that they did use mortar. Hittell states that Humboldt found lime mortar in Equador. Others state that they used mortar looking like clay, but hard as stone. Prescott, on the authority of contemporaneous reports by the Spaniards, states that they used a mortar of clay mixed with lime, and also that in the finer joints they used a fine bituminous glue for mortar, but this last does not seem to be upheld by others.

Peruvian Adobe. Whatever the uncertainty as to the exact nature of Peruvian mortar, their skill in the use of adobe is beyond dispute. Adobe is simply sun dried brick, such as has been used by many different barbaric nations, and by savages in the higher culture stage. Adobes are made by kneading clay with water, sometimes with fibrous materials added to give them greater strength. Reference in the Bible to this practice of the Egyptians will occur to all.

After made, the adobe brick are set to dry, and turned after a proper interval to insure uniform drying of all sides. In general adobe is not suited to any climate where there is much rainfall, and walls made of it crumble after comparatively short periods of time, but in the case of Peru adobe structures still exist after nearly 400 years' exposure to the elements, even in some localities where there is a heavy rainfall.

The Peruvians are credited with having made the best adobe ever manufactured by any nation. Many surmise that they used some special material, or had some special process, the secret of which is now lost. Hittell states that in other countries with twenty inches of rainfall annually, adobe walls, if left uncovered, sink down within a few years into mere heaps of earth, but that in Peruvian districts where rain sometimes comes in torrents, adobe walls more than thirty feet high have stood for more than four centuries without a roof, and so perfectly that they have preserved their sharp corners and decorations. He further states that in some cases a material similar to that in the adobes was built into walls of monolithic character, instead of being manufactured into blocks.

107. **Ancient Peruvian Masonry.** The dispute as to the character of the mortar used in ancient Peruvian masonry has already been mentioned in Article 106. The Peruvians used both cut and uncut stone masonry. In some of their structures, the individual stones were very large. For example, in the fortress of Cuzco, in whose construction 20,000 men are reported to have been engaged for fifty years, one stone has been measured whose dimensions were 27 ft. x 14 ft. x 12 ft., and Hittell states that in another instance a single stone weighs 360 tons. He also states that stones 15 ft. x 12 ft. x 10 ft. are numerous in this structure. They would probably weigh 150 tons each. Such blocks of stone were transported long distances by the combined efforts of many men. In the best Peruvian cut stone masonry the stone fitted so closely that there is not any mortar which can be noticed and in most places not sufficient room to introduce a thin knife blade. Squier states that in no other part of the world had he seen "stones cut with such mathematical precision and with such admirable skill."

Porphyry, basalt, and granite were used in the principal architectural work, and are said by Hittell to have been very hard.

Illustrative Lantern Slides. No. 311. General view of the remains of the fortress walls at Cuzco. No. 312. Close view of the fortress walls at Cuzco., showing character of the masonry. (Both the above from Baldwin's Ancient America.) These illustrations show the comparatively crude and very massive character of the masonry. No. 310. Cyclopean wall at Chanchan. (Encyclopedia Britannica.) No. 38. Wall of Inca Palace, Cuzco. No. 330. Ruins at Ollantaytambo; and Nos. 329 and 331, the 12 angle stone, at Cuzco. (All three from Wright's Peru.) Showing character of the Peruvian masonry.

108. **Ancient Peruvian Architecture.** The ancient Peruvian architecture was comparatively crude. The structures were strong, massive, and durable, but did not show a high degree of artistic skill in their design.

There were many architectural structures, some of them of great magnitude. The fortress of Cuzco was an elevation above the city, and showed a very high degree of military skill in its design as a fortification. The great temple of the Sun, at Cizco, was another of the important Peruvian architectural structures. It was 300 feet by 200 feet, and was especially noted for its lavish ornamentation with gold. A thick sheet, six inches wide, ran around the outside as a frieze, with a similar decoration in every apartment. In the room

of the sun a large plate of gold, shaped and engraved to represent that luminary, and decorated with precious stones, was so placed on the wall that at a certain day the rising sun would strike directly upon it through a large open doorway. Attached to this temple were large gardens, containing ornamental plants and animals made of gold and silver.

Nevertheless, as has already been stated, in general design, Peruvian architecture was crude and practically all of one type. The structures were low, and the walls very massive. The rooms did not communicate with each other, but opened upon a court. The wall openings were often narrower at the top than at the bottom. The roofs were generally of wood or straw, but a few had bell shaped coverings of a composition of earth and pebbles. There was comparatively little cut stone ornamentation in Peruvian architectural structures.

Illustrative Lantern Slides. No. 301. Ruins on Titicaca Island, supposed to be the most ancient ruins found in Peru. Lake Titicaca is admitted to be the center of their most ancient culture. No. 303. Ruins at Pachacmac. Pachacmac, about twenty-five miles south of Lima, was one of the religious centers of ancient Peru and the great extent of these ruins gives an idea of the vast amount of architectural construction throughout the Peruvian Empire. (Both from Baldwin's Ancient Ameriea.) No. 327. The southwest part of Pachacmac, from the north. No. 328. Entrance to principal palace at Pachacamac. (The above two from Wright's Peru. No. 304. Edifice with gateway, at old Huanaco. This shows the common Peruvian practice of making the doorways narrower at the top than at the bottom. Peruvian architecture was crude and with little ornamentation. No. 302. End view of the walls at Grand Chimu. Detail of architectural decorations at Chimu-Chaucho. (The above two from Baldwin's Ancient America.) No. 313. Square Chulpa, or burial tower, in Peru, illustrating tower construction on a small scale by the ancient Peruvians, most of whose architecture was restricted to buildings of one story. No. 317. Facade of palace at Chanchan. Walls 20-30 feet high. View shows decoration by carvings of animals. (The above two from the Encyclopedia Britannica.) No. 315. Niche in facade of Palace of Manco-Ccapac. No. 319. Ruin of Temple of the Inca Viracocha, near Cuzco. No. 320. Ruins of an Incas Palace. No. 321. Entrance to an Incaic house, Cuzco. The above five are from Wright's Peru, and illustrate details of Peruvian architecture.

109. **Ancient Peruvian Cities.** In the ancient Peruvian cities, as in the case of ancient Mexican cities, the houses of the common people were of one story and with thatched roofs. The better houses were of stone, and only one story high. They had no windows but had doorways in the gables with an external ladder or stairway to the attic. A few buildings had two stories. In the two story buildings the entrances to the second story and attic were on the outside. There were no chimneys. The doorways were closed with curtains.

The streets were narrow and long.

The principal cities were Cuzco, the capital, and Quito, in the northern part of the empire, both large and populous. In the description of Cuzco given in Prescott's Conquest of Peru, he states that the streets were generally straight and at right angles with each other with four principal streets radiating from the public square. He further states that there were several public squares, corresponding to small modern parks, but used for religious ceremonies. The main public square and many other parts of the city were paved with fine pebbles. Throughout the heart of the capital ran a river of pure water, the banks and sides of which, for a distance of "twenty leagues," were faced with stone. Across this river were many bridges, constructed of broad flat stones.

Illustrative Lantern Slides. No. 323. Ruins of the eastern street at Pachacamac. No. 324. An Incaic street, Cizco. (Both from Wright's Peru.) Showing narrow streets lined with masonry walls of dwellings.

110. **Sanitary Engineering in Ancient Peru.** The same channels used for irrigation purposes and to be described below, also supplied water for drinking. Hittell states that golden pipes were used to bring water to the Temple of the Sun at Cizco.

Illustrative Lantern Slides. No. 325. An Inca fountain, Cuzco. (From Wright's Peru.)

111. **Ancient Peruvian Irrigation.** The ancient Peruvians conducted very extensive irrigation operations. The conditions for irrigation were favorable, since the higher portions of the Andes supplied water in exhaustible quantities for irrigation during the summer months through the melting of ice and snow, with plenty of fall to bring it down to the arid lands.

The Peruvians constructed their irrigation works on a very large scale. Great reservoirs were made in the mountains, and the water was led to the fields in artificial channels, often 40 or 50 miles long. In places these were cut or tunneled through hills, or cut into the side of steep cliffs. They were lined with stone, in loose soils, to prevent seepage, and were sometimes covered to prevent evaporation. They were sometimes supported on great embankments where they were taken across ravines.

In other cases, as stated by Hittell, the Peruvians made use of the principle of the inverted siphon for crossing ravines.

It is stated that some of these ancient channels are still in good order, and continue to furnish water, though the sources from which it comes are now unknown.

Prescott states that, in the district of Condesuyu, one of their ancient acqueducts was between 400 and 500 miles long. He states that these acqueducts were brought from some elevated lake, or natural reservoir, in the heart of the mountains, and that they were fed by other basins which lay in their route, and that often rivers and marshes were crossed on the way.

Near Caxamarca, a channel is still visible which they excavated in the mountains to give an outlet to the waters of a lake which rose in such a height in the rainy season as to threaten to inundate the surrounding country. Prescott further states that, in the valley of the Nasca, "ancient water courses of the Incas, measuring four or five feet in depth by three feet in width, and constructed with large blocks of masonry, are conducted from an unknown distance." He further states that the quantity of water from these irrigation channels to be used by each occupant of the land was carefully prescribed by law, and that its distribution was superintended by royal overseers.

The Peruvians also expended a great deal of labor in terracing the sides of the hills and mountains, where these were too precipitous to be tilled. They faced their terraces with stone walls, and in some cases even cut into the solid rock, bringing in earth to form an artificial soil. Similar terracing of the mountain sides can be seen at the present day in the mountains of the Philippine Islands in connection with irrigation.

In other cases where the surface soil was arid, but where there was an inexhaustible supply of ground water at a greater depth, the ancient Peruvians dug out the soil from considerable areas, sometimes to a depth of fifteen or twenty feet, facing the excavated area with heavy walls of stone. The bottom of the excavation was then cultivated.

Illustrative Lantern Slide. No. 326, Andenes, or artificial terraces. From Wright's Peru.

112. **Ancient Peruvian Navigation.** Hittell states that, having no suitable trees near navigable water, the ancient Peruvians built no boats; but that they made rafts of logs, which were often rendered more buoyant by the use of skins. He also states that they used both paddles and sails for propelling such rafts, and that they were used for the transportation of guano from the inlands of the mainland. One of the early incidents mentioned

in Prescott's Conquest of Peru is the meeting between one of the first Spanish ships to reach Peruvian waters and a raft of this character at sea. Such rafts were known as "balsas," and Prescott says that they are still the most commodious means of transportation of passengers and luggage on the streams and along the shore of this part of South America.

For this purpose they are supplied with huts and cabins. The description of the one first encountered by the Spaniards states that it was made of large logs of a porous light wood, tightly lashed together, with a deck of reeds. Two masts in the middle sustained a large square sail of cotton. The craft was steered by a rude rudder and a movable keel of plank was inserted between the logs. Prescott states that at a distance this raft with its large sail looked like a caravel to the Spaniards who first saw it. The Spaniards found upon it a party of Indians engaged in trading along the coast.

Illustrative Lantern Slides. No. 334, a loaded Balsa-Parta. No. 333, Llamas embarking on a Balsa at Puno, Lake Titicaca. Both from Wright's Peru.

113. **Land Transportation in Ancient Peru.** In methods of land transportation, the ancient Peruvians were in advance of the Mexicans, in that they built regular roads, and employed animal power for the transportation of freight.

The Llama. The burden bearing animal of the ancient Peruvians was the llama, which also furnished them with wool. Great flocks of these animals were kept pastured in the higher mountain regions, and were carefully protected by law.

In the transportation of freight, each animal, according to Prescott, carried a load of a little over 100 pounds, but the llamas move in droves of 500, or even 1000 so that the aggregate burden carried is large. The whole caravan moved only about three or four leagues per day, and each animal picked up an easy subsistence from the loose herbage upon the sides of the mountains.

Illustrative Lantern Slides. No. 335, Llamas carrying burdens. From Wright's Peru.

Peruvian Roads. Ancient Peruvian engineering is especially notable as to the magnitude of their work in road building. They had a series of roads connecting all the principal cities in the Empire; and including, especially, two great main roads, parallel with the coast line, each of which was about 2000 miles long. Humboldt thinks these roads are "among the most useful and gigantic works of human enterprise."

They are stated to have been twelve to fifteen feet wide, with a paving of flat stones, or small stones laid in a "cement," so hard that it stands as a bridge after the soil beneath has been washed away in some places. (No true cement was known to the Peruvians.) As there were no vehicles, steep grades and even steps in the roads were not objectionable.

One of the great roads followed close to the coast line, and the other parallel to it, far up in the Andes. On this latter road, especially, tunnels, bridges, embankments and cuts into the steep cliffs were numerous. Hittell mentions one case where a bridge was approached on one side by a tunnel several hundred yards long.

At intrevals of four or five miles on the main traveled roads, huts were provided for the accomodation of relays of runners, and about every eleven miles larger houses for the accomodation of high officials. The ancient Peruvians maintained a regular system of carriers by which messages and small packages were carried with great rapidity from one portion of the empire to another. In this particular, both the ancient Mexicans and Peruvians were in advance of contemporary nations of Europe.

Illustrative Lantern Slides. No. 336. East slope of Cordilera's at Chanchamayo. No. 337. Curve of San Bartolome, Orayo Railway. Both from Wright's Peru. Showing stupendous difficulties to be overcome in road building in the Andes.

Bridges. The ancient Peruvian bridges which crossed rivers and mountain gorges, were made on the suspension principle. Cables of twisted osiers, or in some cases of maguey fibres, were constructed to swing across the chasm or river to be bridged with osier cables 210 feet long by ten inches in diameter. This bridge spanned the Opuremac river at a height of 100 feet, with a clear span of 108 feet.

Illustrative Lantern Slides. No. 514-515-516. Three views of a native suspension bridge in the Himalaya mountains, illustrating the general character of such suspension bridges as were built by the ancient Peruvians and described above. These views are from Harper's Magazine, March 1, 1906. No. 338. Ancient suspension bridge, on road from Huan Cayo to Cometo. From Wright's Peru, showing later adaptation of the primitive suspension bridge.

CHAPTER X.

CHINESE ENGINEERING.

114. **China and the Chinese.** The empire of China embraces an area approximately four million square miles, which is greater than the total area of the United States, including Alaska. In this total, however, are included a number of outlying provinces and dependencies, such as Manchuria, Mongolia and Tibet, whose connection with the central government is not very close. The population of China is roughly estimated at 400,000,000. The empire proper is 1,500,000 square miles in area, this being equal, approximately, to the area of the United Strates east of Colorado. This empire proper is divided into eighteen provinces, ranging in area from 35,000 to 170,000 square miles each. Each province corresponds, therefore to an American state, since Indiana has an area of 35,700 square miles, and California, 156,000. The empire proper includes the valleys of two great rivers, namely, the Hoangho or Yellow River, in the north and the Yangtze in the south. Still farther south is another river valley of considerable size, that of the Takiang. These fertile river valleys contain, according to Hittell, approximately one million square miles of fertile, cultivated land, which Hittell states is greater than the total cultivated area of Europe. Defended on the east by a long range of coast, with many harbors, and on all other sides by mountain ranges, and deserts, the empire of China was a very favorable country for the early development of an advanced culture.

The Chinese race originally entered this territory from the northwest. Its birth place is thought by some good authorities to have been in Western Asia, probably south of the Caspian Sea. Entering from the northwest the Chinese people gradually advanced southeast along the valley of the Yellow River, and to the south until the entire present area of China proper came under their dominion. The race has continued practically unchanged until the present time. Although foreign dynasties have twice been imposed upon the empire as the result of successful invasion, the conquerers in each case adopted the language and customs of the Chinese. We have no other instance of an existing nation where a single race and culture have been so long in continuous occupation and dominion of a country.

115. **Chinese History.** The date at which the Chinese race first entered China from the northwest is not certain. Chinese historians attribute fabulous antiquity to their earliest civilization. Most authorities assign a date between 2300 to 2400 B. C. to the reign of their earliest authentic monarch, though others give a date between 2800 and 2900 B. C.

The country takes its name from the dynasty of Tsin, who united the various peoples of the empire proper under one sway between 200 and 300 B. C. Tsin also began the great system of Chinese canals, and started the Great Wall.

Confucius, the great Chinese religious teacher, lived 551 to 475 B. C.

The Chinese alphabet is of very ancient origin, some traditions assigning a date as early as 2800 B. C.

The practice of requiring examinations as a pre-requisite for admission to office has prevailed since about 1200 B. C. The present system of examinations goes back to about 700 A. D.

The Grand Canal of China was in process of construction from about 200 A. D. to 1289 A. D.

Parsons states that the Tang Dynasty, 618 to 908 A. D. marks perhaps the zenith of Chinese development. He claims that at that time Chinese culture was in advance of that in Western Europe.

Christianity was introduced into China by the Nestorian Monks at about 500 A. D., and then died out about 845 A. D.

In 1213 occurred the first foreign conquest of the country, by the Mongols, under Genghis Khan.

Christianity was re-introduced in 1682, by the Jesuits, after a previous effort 250 years earlier.

The first foreign settlement in China was made at Macao, in 1557, by the Portugese.

The second foreign conquest of the country was by the Manchus, in 1644, and the dynasty then imposed has continued until the present time. The Manchus imposed the queue upon the Chinese, as a token of subjugation.

116. **Chinese Culture.** The Chinese are ranked among the barbarian nations, and in these lectures no attention will be given to many recent signs of awakening to western civilization.

Their culture is most remarkable for its unchangable character. Hittell states that there has been less change in Chinese culture in 4000 years than has occured in 1000 in any other nation.

As illustrating Chinese blind respect for precedent, Parsons gives a view of a bridge on a certain road, which is maintained over level dry ground without any apparent present reason for its existence. At some very remote period in the past a stream crossed the road at this point and the bridge which was necessary then has been retained ever since.

Illustrative Lantern Slide. No. 860. Bridge over dry ground (From Parsons' An American Engineer in China, Page 107).

The government of China is nominally a despotism, but, in fact, there is an unwritten constitution, based upon precedent, which the emperor would not dare to disobey. The central authority is administered through two councils, under whom are seven boards. Each of the eighteen provinces has a governor, and groups of provinces, of two or more are under viceroys who maintain separate armies, and in many respects are practically independent of the central authority.

Chinese culture differs from all other in the prominent importance given to *educational qualifications*. There is a regular system of examinations, of different grades; and the annual number of competitors in the lowest class is stated by Hittell to be two million. He also states that this is a larger per cent of the total population than the college students of Europe. Admission to high office in the Chinese Government is absolutely dependent upon success in the competitive examinations. To such an extent has this been carried, that the government is extremely democratic, because admission to the competitive examinations is open to all classes, except these designated as "dishonorables." There is no hereditary nobility except about 40,000 supposed direct decendants of Confucius.

The population is so crowded that a great majority of the people are very poor.

Chinese art is crude and fantastic. This applies to sculpture, painting, music and architecture.

Illustrative Lantern Slide. No. 859. Carved animals lining the road to the Ming Tombs. (From Parsons.)

There are three principal *Chinese Religions*. *Confucianism*, *Taoism*, and *Buddhism*. The latter was introduced from India, and its origin will be discussed in the next chapter.

Confucianism may be said to be the characteristic Chinese religion, since its author, Confucius, was a native of the country. Confucious, however, did not claim divine authority or inspiration. He compiled the records and traditions of the past, and did much thinking and writing on philosophical and moral lines.

Ancestor worship is a very prominent feature of Chinese religion.

117. **Chinese Science and Mathematics.** The Chinese *alphabet,* as has already been stated, is of very ancient origin. It has remained practically unchanged for thousands of years, and is exceedingly difficult to learn and use. Conventionalized hieroglyphics are used, each standing for a word or an idea, so that there are about 24,000 different hieroglyphics, and to learn them all would require a large portion of a man's life . A couple of thousand suffices for ordinary use. There are six different systems of writing.

Illustrative Lantern Slide. No. 841. Showing the same sentence written according to the six different systems. (From China and the Chinese, by Nevins).

The Chinese read in verticle lines from the top to the bottom, and from right to left, with their titles at what is to us the end of the book, and their foot notes at the top of the page.

In Mathematics and astronomy, the Chinese have not attained to eminence. Hittell states that they do not use Hindu numerals in their mercantile houses, but depend upon the abacus, or counting board, for making their computations. Their astronomical observations go back to a remote age. The notions of the Chinese concerning physical science are of the crudest and most fantastic nature.

118. **Chinese Industries and Commerce.** Chinese industries have been carried on in much the same manner as in other barbaric nations, by many separate crafts. The Chinese are especially noteworthy for having organized the first rude idea of so many great industrial inventions. According to Hittell (Mankind in Ancient Times. Vol. 2.

They practiced silk weaving and distillation 2700 years before these arts were known in Europe.

They coined bronze as early as 1100 B. C.

They made sugar before 600 B. C.

They had canals exclusively for navigation, the magnetic needle, pisciculture, artesian wells, natural gas fuel, petroleum lamps, paper and lacquer ware, 100 B. C.

They had explosive powder, cannon, porcelain, tea as a common beverage, and spectacles, 600 A. D.

They had invented movable type, cards and paper money, and had discovered inoculation for small pox, 1150 A. D.

The Chinese may have invented the spinning wheel, water wheel, and cultivation of rice and sweet potatoes.

Prior to 1150 A. D., they had made some important industrial invention or discovery for every century, during a period of 2000 years; but since then none.

Although Chinese industry is remarkable for having originated the idea of so many great inventions and discoveries, it perhaps is even more remarkable for the incompleteness of these same industrial achievements. For example, they had canals for navigation without locks; gun powder without guns; the magnetic needle without compass pivot; printing without printing presses; type without a foundry; paper without a paper mill. The western civilized nations developed these great inventions to the widest usefulness within a very short time after first discovering the germ ideas.

In several lines of industry, however, China has been in advance of western civilization. They long held the lead in manufactures of silk and porcelain, for example.

In *agriculture,* owing to very dense population, the Chinese have made the best use in their power of all land fit for tilling. Practically all of such land

is made to produce food for man. It is stated that they have practically no pastures, and they have terraced the hills in many places in a manner similar to that already described for Peru. Much of the land is irrigated by water raised by hand power.

In fact, hand power is most extensively used by the Chinese in cultivation, land transportation, and other industries.

The Chinese have had a very extensive commerce from a very early date. The internal commerce has largely been carried on by the aid of the great waterways of the country which have been supplanted by an extensive system of canals from a remote period. From time immemorial there has also been a very large coast wide trade.

Illustrative Lantern Slides. No.839. An ancient Chinese coin, about 9 A. D. (From China and the Chinese by Nevins). No. 812. Chinese sawyers at work making boards. (From Chinese Characteristics by ———. No. 858. A Chinese saw mill. (From Parsons).

119. .**Chinese Tools and Mechanical Devices.** Very little will be said upon this subject. The early material for their tools and mechanical devices was bronze, but since a remote date this has been supplemented by iron. By far the greater part of their tools and mechanical devices are for hand use, and of very simple nature.

120. **Chinese Mining and Metallurgy.** China is stated to be very rich in mineral deposits but these have been little worked as yet. In addition to the usual barbaric mining and metallurgy of gold, silver, copper, and tin, and similar operations for iron, the Chinese have regularly mined and used coal for fuel from a remote period. This is illustrated by the following quotation from Marco Polo's account of his travels in China, about 1280 to 1290 A. D. In speaking of the province of Cathay, in northern China, he says: "Throughout this province there is found a sort of black stone, which they dig out of the mountains, where it runs in veins. When lighted, it burns like charcoal, and retains the fire much better than wood, in so much that it may be preserved during the night, and in the morning be found still burning. These stones do not flame, except a little when first lighted, but during their ignition give out a considerable heat. It is true there is no scarcity of wood in the coutnry, but the multitude of inhabitants is so immense, and their stoves and bakeries which they are continually heating so numerous, that the quantity could not supply the demand—and the stock of wood must soon prove inadequate for such consumption, whereas these stones may be had in greatest abundance, and at a cheap rate." It appears then, that the Chinese were making extensive common use of coal for fuel in the 13th century, at a period when western Europe did nothing of the kind.

121. **Chinese Ceramics.** The statement has already been made that China was for a long time preeminent in the manufacture of porcelain. Miss Young, in her book on "The Ceramic Art," states that there is a Chinese legend to the effect that pottery was invented by Hwang-ti about 2700 B. C., and that the beginning of its manufacture may reasonably be fixed at about that time. Porcelain, according to some authorities, was invented between 185 B. C. and 88 A. D., in the Province of Hunan. "Crackelware" has been made in China at least since the Tong Dynasty, 960 to 1275 A. D., and probably much earlier.

Marco Polo, in his book written in the 13th century, described the Chinese porcelain industry at a certain city in China, and stated that each workman collected the clay and stored it for the use of his children and grandchildren. They mined it and left it exposed in heaps for thirty or forty years to the action of the sun, wind and rain to refine it.

The Chinese have made extensive use of enameled brick, and porcelain tile, of many colors, in connection with their architecture. Perhaps the most famous example is the porcelain tower of Manking, for description of which see Article 123.

122. **Chinese Masonry.** Chinese masonry has been built from time immemorial, of both sun dried and burned brick, and of stone.

The greatest single example of Chinese masonry is, of course, the *Great Wall* of China. This was constructed in the 3rd century B. C., as a defense against invasion by hostile tribes and nations from the north. Its eastern end is at the sea coast, on the Gulf of Liaotung, about 150 miles east and northeast of Pekin. The great wall crosses the Yellow river twice in its course and ends about 850 miles due west of Pekin. In Cram's atlas, the total length of its main portion scales about 1250 miles. There are two sections where the wall is double, with large areas enclosed between the two walls. One of these would add about 300 miles, and the other about 200 miles to the total length, which therefore would scale upon the map approximately 1750 miles. Various authorities, however, give the total length at 1500 miles, while others say 1250 miles. Hittell states that the wall is from fifteen to thirty feet high, the sides being built of stone and the inner mass of earth. He also states that towers forty feet high were placed approximately 300 feet apart. Gwilt, in his Encyclopedia of Architecture, gives the height as twenty feet, and the thickness at the base as twenty-five feet, diminishing to fifteen feet at the top. There is a parapet wall four or five feet high, on each side at the top. According to some authorities the wall was made of brick in some localities. Barnes states that it was built by the Emperor Hwang-ti. Parsons says that it was started by Tsin.

Illustrative Lantern Slides. No. 826. The great wall of China at a precipice. No. 827. General view of the great wall of China. No. 814. A top view of the great wall of China. (From Chinese Characteristics.) No. 805. Pictorial view and 806 top view of the great wall. (From The Strand Magazine, August, 1906.)

123. **Chinese Architecture.** It has already been stated that Chinese art is not usually admitted to be of a very high type. Chinese architectural constructions are fantastic rather than beautiful. "The Chinese have never had a great architect, nor have they ever built a great palace, temple, castle, bridge, or tomb. There is a Chinese style of architecture, but it is curious rather than artistic, and finds its highest expression in the pagodas, which are ecclesiastical structures, and yet are useless for public worship, and not well adapted to sacerdotal residence." (Hittell.) The above statement might well be qualified, in so far as it refers to ancient Chinese bridges, some of which have been of considerable magnitude, and show much skill in design. (See Article 128.)

One of the most famous Chinese architectural structures was the Porcelain Tower at Nanking. It was destroyed by the Chinese rebels in 1856. According to Miss Young, ("The Ceramic Art"), this tower was originally built in 844 B. C., and was rebuilt in 371 to 376 A. D., and again in 1412 to 1431 A. D. Authorities differ as to the dimensions of this structure. Miss Young states that it was 353 feet high, while Hittell says 261 feet. The shape was octagonal, with a diameter, according to Hittell, of forty feet at the ground. According to some authorities, there were nine stories, each having a projecting roof, with a bell at every corner of each roof. The structure was built of brick, with a facing of white, yellow, green and red porcelain tiles.

There are many structures in other Chinese cities. George Kennan (in the Outlook, March 31, 1906) describes the Soochow pagoda as being an octagonal tower of masonry, 300 feet in circumference, 250 feet high, in nine stories.

The *Chinese pagoda* may be regarded in fact as their most important example of original architectural design. According to Parsons, (an American Engineer in China), nearly every city possesses at least one of these peculiar structures, which "therefore, fairly dot the surface of the country. Their purpose appears to be twofold, either as monuments commemorating the virtues or munificence of some departed benefactor, or as agents of "feng shui" (literally wind and water), the spirit genius of good and evil which, if properly propitiated, will ward off pestilence and famine, and permit only

prosperity and happiness to visit the neighborhood. These very curious towers are of great antiquity, Chinese records authenticating their origin at least as far back as the early part of the Christian era. In size they vary from the little ones, which are nothing more than roadside shrines, to what was once the most beautiful and largest—the celebrated, porcelain pagoda of Nanking, destroyed in the Tai-ping rebellion." Parsons also states that the most prominent pagodas vary in height from 100 to 200 feet, and that they are usually octogonal in plan, with straight but tapering sides, and are usually composed of an odd number of stories. He also states that unfortunately most of the large pagodas are being allowed to crumble and decay.

Illustrative Lantern Slides. No. 802. Chinese pavilion and entrance gate of temple. (From Rosengarten, Architectural Styles.) No. 803. Pavilion of great temple at Canton. (From Rosengarten, Architectural Styles.) No. 801. The Porcelain tower at Nan-king. (From Ceramic Art, by Miss Young.) No. 804. Pagoda of Tung-Chow. (Reference not ascertained.) No. 842. Chinese Architecture. A good picture apparently showing entrance to a temple. No. 843. Temple of Heaven, Pekin. (From With the Empress Dowager.)

124. **Chinese Cities.** The Chinese Empire has been noted since remote ages for the magnitude of many of its cities. In these cities as in those of other barbaric nations, the streets are, as a rule, very narrow and also, as a rule, they are neither well paved nor clean. There are some instances, however, of streets well paved with stone. In Marco Polo's travels, he describes Hang Chow, the capital of southern China, and makes the following statement: "The streets of Kinsai (Hang Chow) are all paved with stone and brick, and so likewise are all the principal roads extending from this city through the Province of Nanji." He further states that the main street of the city, leading clear through it, was paved for a width of ten paces with stone or brick on each side, with an intermediate space filled with small gravel, and with an arched drain for carrying off storm water into the neighboring canals. Modern writers are not very enthusiastic generally in their descriptions of China cities.

Illustrative Lantern Slides. No. 854. Wall of Tartar City. No. 857. Street in Hu Nan. No. 855. View of Village of Kiwangtung. (All from Parson's An American Engineer in China.)

125. **Chinese Sanitary Engineering** We have little information bearing upon this subject in ancient times. Modern writers state that their sanitary arrangements are of the most primitive nature, and are the cause of much offence to foreigners living in Chinese cities.

126. **Chinese Irrigation and Hydraulic Engineering.** The Chinese have practiced irrigation extensively in connection with their agricultural operations. However, we do not find mention of large irrigation works. Their devices for lifting water for irrigation purposes are usually operated by hand power, though animals are used to a limited extent, and they even make use of water power.

The most extensive hydraulic constructions of the Chinese, aside from the canals, appear to be the great dikes with which they have enclosed the channels of the Yellow River, protecting the adjoining country from floods. They began the construction of these long before the Christian Era. In some places the dikes have been in existence so long that, by the deposit of silt, the bed of the river is stated to be higher at the present time than the level of the adjoining country.

More noted than the dikes is the system of canals for navigation, which are also used to some extent for the purposes of irrigation. Between the Yellow and the Yangtze rivers lies the "Great Plain" of China, and in this portion of the country an extensive network of canals has been constructed, and they are not entirely lacking elsewhere.

Of the canals the *Grand Canal* is the most noted. It extends parallel to the coast from Han Chow on the south to Tientsin on the north. In its course it crosses the Yangtze and the Yellow rivers. The total length is about 650 miles, or as far as the distance from Washington to Chicago. For a considerable portion of its length the width is 200 feet. For a considerable distance it is constructed 20 feet above the surface of the ground. In other places there are cuts 60 feet deep. According to George Kennan (Outlook, August 31, 1906), this canal was under construction from about 200 A. D. to 1289 A. D. He states that there are hundreds of lateral branches and feeders and that it unites 20,000 or 30,000 cities and villages and covers the entire eastern part of the empire with a watery network.

Illustrative Lantern Slides. No. 845. Chinese chain pump operated by man power. (From Ewbanks' Hydraulics.) No. 838. Irrigation by chain pump. (From China and the Chinese, by Nevins.) No. 825 Drawing water by bullock power (From Stoddard's Lectures.) No. 846. Wheel for elevating water for irrigation purposes. (From Ewbanks' Hydraulics.) No. 856. River wall on Yangtze Kiang, at Wu Chang, opposite Han Chow. (From Parsons.)

127. **Chinese Navigation.** Chinese navigation has been conducted on a very extensive scale from most remote periods for the purpose of internal and coastwise trade. The rivers and canals are covered with tens of thousands of crafts of different sizes and shapes. There is a large population living entirely upon such boats. Commerce is carried on in large volume on the rivers of the country, but according to methods which seem extremely crude to civilized visitors.

From time immemorial, the Chinese have also made use of sea-going vessels of considerable size and in great numbers. They have developed a peculiar type of ship, known as the junk, which is clumsy in appearance but cheap in cost, and has good sailing qualities. They make these junks in sizes up to 2000 tons. In Marco Polo's book, written in the 13th century, he gives a quite lengthy description of the ancient Chinese ships which were built for trade with India. He states that they were built of fir timber, with one deck, and that in some cases the space below the deck was divided into sixty or more cabins, each for an individual merchant. He states that they had good helms, and that the large ships had four masts, each carrying one sail. Some of the large ships had water-tight bulk-heads, to the number of thirteen, so that the Chinese anticipated the rest of the world in dividing ships into water-tight compartments. He also states that these ancient ships were double planked, calked with oakum inside and out, and fastened with iron nails. The largest ships required 300 men for the crew of each, and were capable of carrying 5000 to 6000 mat bags of pepper. They had sweeps as well as sails, four men operating each sweep. Each ship of the large class was accompanied by two or three ships of smaller size, having crews of 60 to 100 each. He also states that each ship had ten boats slung over the sides. With a fleet of such ships Marco Polo made a voyage from China to the western part of Asia in the 13th century.

Marco Polo also states that in one Chinese city he found not less than 15,000 ships, and that in each of two other towns he found more. Even this statement is not so surprising as that of Hittell, that more than 80,000 boats navigate the waters around the city of Canton.

Illustrative Lantern Slides. No. 817. View of the multitude of boats near the city of Canton, showing the bat-like sails, and forests of masts. No. 819. Showing waters near Canton, literally covered with thousands of boats. No. 818. Showing nearby view of Chinese boats near Canton. No. 822. A typical Chinese craft for inland navigation. No. 824. A Chinese junk. (All the above from Stoddard's Lectures.) No. 833. Chinese trading junk. (From China and the Chinese, by Nevins.) No. 861. Freight boat poling up stream. (From Parsons' An American Engineer in China.)

128. **Chinese Land Transportation.** Chinese land transportation is mainly by man power. Human labor is cheap, while animals are scarce, and rail-

ways are unknown over most of the empire.

The *roads* are poorly constructed and made principally for foot traffic. In many instances, a narrow track is roughly paved with stone, and there is an earth foot-way alongside.

In *transporting* freight, various devices are used by which the carriers can support the weight. Where the burden is small, a carrying stick may be used, supported across both shoulders behind the neck, with the weights balanced on each side. In the case of heavier weights, two or any number of men may be used, with the weight distributed to each man on the lever principle, by a suitable arrangement of carrying poles.

From very ancient times, the Chinese have shown great skill in the construction of *bridges*. Marco Polo, already quoted so many times, writing in the 13th century, says that at Hung-Chow, in southern China, there were over 12,000 bridges of various sizes. He described a stone arch bridge, ten miles west of Pekin, 1500 feet long and 40 feet wide, composed of twenty-four arches, each of sixty-three feet span, center to center, while the bridge was adorned with considerable ornamental construction. It is interesting to compare with this ancient account the description of Chinese bridges in Mr. Parsons' recent book, "An American Engineer in China," also already quoted. Mr. Parsons seems to have a high idea of the abilities of the Chinese in designing and constructing bridges. Most of their important bridges are stone arches, but Parsons gives one view of a large wooden cantilever bridge.

In studying Chinese bridge engineering it should be remembered that their roads are not designed to accommodate vehicle traffic. Hence types of bridges have been constructed which were well adapted to foot traffic and the passage of animals, but which are not adapted to vehicles. The "camel-back" bridge may be considered a typical Chinese design. It has a very high waterway in the center to permit the passage of boats without lowering their sails, masts, while on each side of this water-way is a very steep grade, or even, in many cases, flights of steps. Some of these "camel-back" Chinese bridges are very beautiful structures.

Illustrative Lantern Slides. No. 834. Mode of carrying burden by one person. No. 835. Two Chinese carrying burden. No. 840. View of procession, showing burden carried by four men. No. 836. Chinese gentleman riding in Sedan chair. (All the above from China and the Chinese, by Nevins.) No. 820. A Chinese wheelbarrow used for carrying freight. No. 823. A wheelbarrow carrying two passengers, also showing coolie with burden stick carrying two balanced weights. (From Stoddard's Lectures.) No. 837. Chinese cart, drawn by two bullocks and a horse. (From China and the Chinese, by Nevins.) No. 829. A Chinese cart drawn by donkey. (From Stoddard's Lectures.) No. 813. A Pekin cart drawn by two donkeys. (From Chinese Characteristics.) No. 847. Coolie using carrying stick. No. 828. Boy carrying coal from mine. No. 830. American Engineer in Sedan chair. No. 807. Procession of carriers—the primitive railway train. No. 810. A typical Chinese road. No. 831. Descent from Cheling Pass, showing road paved with stone, worn by bare feet of carriers of many centuries. No. 832. A Chinese road paved with stone, showing groove worn by wheelbarrow traffic. (All from Parsons.) No. 809. Chinese bridge over Grand Canal near Canton, China. (From Engineering Studies, by Fowler.) No. 816. A Chinese bridge. (From Chinese Characteristics.) No. 850. A beautiful "camel-back" bridge near Pekin. (From Engineering Studies, by Fowler.) No. 851. A very old arch in Hu Nan. No. 852. Ping-hsiang bridge. No. 853. A beautiful single span. No. 206. Arch near Pekin. No. 849. A small bridge. No. 848. A very old wooden cantilever bridge over La Ho at Li Hing. (All from Parsons' An American Engineer in China.)

129. **Japanese Engineering.** No special study will be made in these lectures of Japanese engineering. In so far as it belonged to the barbarian culture stage, it was very similar to Chinese engineering. The Japanese have, however, recently made good claim to attainment of civilized culture. Their

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modern engineering is largely along the lines of western civilization, and while exceedingly interesting and showing much skill, has, as yet, little importance in connection with the history of engineering.

Illustrative Lantern Slides. No. 4230. Ancient Japanese bridge. No. 4229. The famous "Spectacle Bridge" in Japan. No. 4231. Modern Japanese bridge, showing similarity of their modern engineering work to that of western engineers. (All the above from Engineering Studies, by Fowler.)

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